Carbon-Impaired Investment: Understanding Stranded Assets in an Uncertain Energy Future

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See footnotes at end of text.

Definition

Expectations of future economic conditions guide decisions to invest liquid capital in illiquid assets. If economic conditions are less favorable than expected, investment returns may decline so much that, an investor would have altered their investment decision in order to avoid part of the investment becoming "stranded" in an underperforming asset. The longer the investment horizon, the less certain we can be of what conditions will prevail and the more likely some of an asset's value will become stranded.

Assets underperforming expectations is a common occurrence and financial accounting standards offer clear guidance on how to value them. Accounting standards refer to assets as "impaired" when their market value falls below their book value less depreciation. For example, U.S. firms follow Financial Accounting Standard No. 121 and statement 144 in "Accounting for the Impairment of Long-Lived Assets and for Long-Lived Assets to be Disposed of" when their assets undergo a significant loss in market value, loss in productivity, or encounter higher-than-expected fixed or operating costs. Climate-specific examples abound for such situations; e.g., adverse regulation in the form of GHG performance standards, physical damage from more intense or frequent storms, or higher fixed costs for constructing climate-resilient fixed assets (i.e., require adaptation capital).

Causes

Environment

The natural environment provides a suite of services and assets to the economy. Changes in the state of the environment can damage or otherwise degrade the performance of natural or built assets leading to impairment. The EPA Climate Impacts and Risk Analysis (CIRA) project provides a broad assessment of climate-related asset risks.[1] For example, sea level rise may degrade or demolish coastal real estate (Bin, Poulter, Dumas, & Whitehead, 2011; McNamara & Keeler, 2013). Increased storm frequency and intensity may depreciate and damage existing capital (Bouwer, 2010; Estrada, Botzen, & Tol, 2015; Nordhaus, 2010). Ocean acidification may undermine the health of marine ecosystems and fisheries (Branch, DeJoseph, Ray, & Wagner, 2013; Brander, Rehdanz, Tol, & Van Beukering, 2012; Narita, Rehdanz, & Tol, 2012).

Technology

Technological change, including the discovery of new technologies or improvement of substitute technologies, can reduce the cost-competitiveness of an asset. For example, the shale gas boom was a result of new technology that allowed us to access existing reserves at a lower cost. Natural gas then became cheaper for electricity generation in comparison to coal (Knittel, Metaxoglou, & Trindade, 2015). Improvements in electric vehicle, electricity storage, and renewable technologies have dramatically reduced costs and threaten to strand fossil fuels, coal not least among them.

Preferences

Consumer preferences for the goods and services they consume may change and raise costs or decrease revenue streams associated with an asset's performance. For example, changing consumer preferences on electric vehicles and increased electric vehicle adoption threatens to strand oil resources or oil-using assets (Azar, 2009). Societal preferences and perceptions of risk surrounding nuclear energy changed after the Fukushima Daiichi nuclear disaster, leading to initiatives across various countries to close existing nuclear power plants and stop the construction of new nuclear power plants. Winter tourists may change their preferences on snow sport destinations as ski-resorts experience shorter snow seasons with greater variability within the snow season, subsequently reducing the value of the ski-resorts (Gössling, Scott, Hall, Ceron, & Dubois, 2012).

Policy

Policy and regulatory changes can directly raise the costs or decrease the revenue streams associated with an asset's productivity. Policies may also require higher environmental or safety performance to generate greater public benefits, putting downward pressure on the value of existing production assets as new or retrofit equipment must be added. A cap-and-trade policy, such as RGGI, will increase the cost of carbon-emitting generation, potentially stranding coal-fired assets (Kim & Kim, 2016). However the stranding of coal may tip the marginal cost over the carbon capture threshold and make carbon capture more cost-competitive (Clark & Herzog, 2014; Johnson et al., 2015).

Modeling

A variety of approaches to energy-economic modeling exist. Calibrated simulation models provide a useful diagnostic tool for understanding key economic dynamics under different sets of assumptions or scenarios. A common approach, often referred to as "bottom-up," is to represent a single sector or group of sectors in the economy with high levels of engineering and economic detail but treat the rest of the economy in a reduced form or even fixed way. Larger energy-economy models integrate results from several sectoral supply or consumer demand modules with shared energy price and quantity information coordinated with certain high-level macroeconomic dynamics. General equilibrium models, often referred to as "top-down", represent factor supplies (e.g., capital, labor), intermediate, and final demand quantities and prices for the entire economy at some level of sectoral and regional aggregation.

Bottom-up and energy-economy models excel at providing technologically explicit representations of the physical operations of engineered systems. Their relative weakness is in capturing how inter-industry linkages and substitution behavior may dampen or amplify the total economic costs or benefits. General equilibrium models, particularly those with richer energy technology representations, can provide a worthwhile compromise between explicit representation of engineering detail and key macroeconomic dynamics. This tradeoff is particularly worthwhile in the case of stranded energy resource and technology assets whose value may depend on the full interaction of the surrounding environment, technology, preferences, and policies.

Irreversibility

A model should be able to track and fix investment in the sectors of interest in order to assess impairment and stranding. Models typically fix investments in sector-specific capital stocks by recording the amount of malleable (a.k.a. putty) capital invested and making it non-malleable (a.k.a. clay; cf. Phelps, 1963 on "putty-clay" capital dynamics) often fixing the associated production technology to that prevailing in the period. By fixing and tracking sector-specific capital formation one can compare the cost basis and market value of installed capital to assess impairment or stranding.

Uncertainty

There are two broad categories of how to treat inter-temporal dynamics: recursive and foresighted. Investment decisions in recursive models are based on intra-period market conditions or may follow exogenous rules. Foresighted models' investment behavior is based on current and expected future market conditions. As a result, foresighted models are more difficult to "surprise" with adverse events. Scenario costs measured between the model baseline and policy simulations may understate costs to the extent foresight lowers transition costs and recursive models may overstate scenario costs to the extent investment behavior is overly myopic or rigid.

Substitution

Not all model types make explicit use of substitution elasticity parameters, but they are implied by model behavior. For example, a model designed to choose generation only on cost implies perfect or infinitely elastic substitution. Simulation models may exogenously dampen the ease of substitution by limiting the rate of growth for specific technologies to prevent abrupt changes period-on-period, so-called "bang-bang" behavior (e.g., Hyman et al, 2003, Huppman and Egging, 2014 for discussion). Substitution elasticities are often larger as economic activities are aggregated or longer periods are considered and is an eminent feature of general equilibrium models. Regardless of explicit model structure, the implied degree of substitution between a potentially impaired asset and its substitutes will strongly guide the modeled risk of impairment and stranding.

ARTIMAS

An RTI Macroeconomic Analysis System (ARTIMAS) is a foresighted dynamic computable general equilibrium (CGE) model of the United States, with nine representative households by income, and can be run at national or regional geographies. The model represents 30 sectors with a focus on energy and pollution-intensive industries. ARTIMAS includes a technology-rich representation of the electricity sector based on RTI's Micro-level Environmental and Economic Detail of Electricity (MEEDE) database (Woollacott and Depro, 2016). The MEEDE database provides a unit-level characterization of environmental, engineering, and economic attributes of electricity generators and abatement equipment on the U.S. grid. The electricity sector in ARTIMAS represents approximately 60 electricity generation and abatement model technology configurations based on the MEEDE data. Capital stocks are vintaged by sector and by fuel type in the electricity sector. ARTIMAS tracks emissions for oxides of nitrogen and sulfur, particulate matter, mercury and four types of greenhouse gases in the electricity sector and GHGs from fossil-fuel combustion in the rest of the economy.

Results

We use the ARTIMAS model to evaluate a range of impairment risks, using stylized examples from each of the causes listed above. Impairment risks range from a low-risk example (chosen from environment), to intermediate (chosen from technology and preferences), to a high-risk example (chosen from policy). The impact scales are not intended to be compared. More rigorous simulations would draw on additional data to better articulate and calibrate the phenomena in the examples and might also revise model structure to capture additional factor and commodity market dynamics. We implement the shocks at the outset of the model period and evaluate the extent of impairment through percent changes in the price of capital associated with electricity generation and fossil fuel stocks (Figure 1 and Figure 2, respectively).

Environment

Increases in drought frequency and duration will impact hydroelectric generation capacity in the United States. Bartos and Chester (2015) examine the impacts of climate change on electricity generation in the western United States, where at least 60% of U.S. hydroelectric generation capacity resides and estimate that sustained droughts could reduce hydroelectric generation capacity by up to 8.8%.[2] Droughts could also diminish thermal generation assets with inadequate cooling water, which would in turn be called upon to offset lower hydroelectric generation during drought periods (Zohrabian and Sanders, 2018).

We model the impact of an 8.8% decline in hydroelectric output and do not consider any other impacts of drought (e.g., increased electricity demand for desalinization, reduced capacity of water-cooled thermal plants). A mild drought-induced capacity loss of 8.8% leads to a 3.0% decline in the value of hydroelectricity generating capital and has a negligible impact on other generating assets (Figure 1) and fossil fuel stocks (Figure 2).

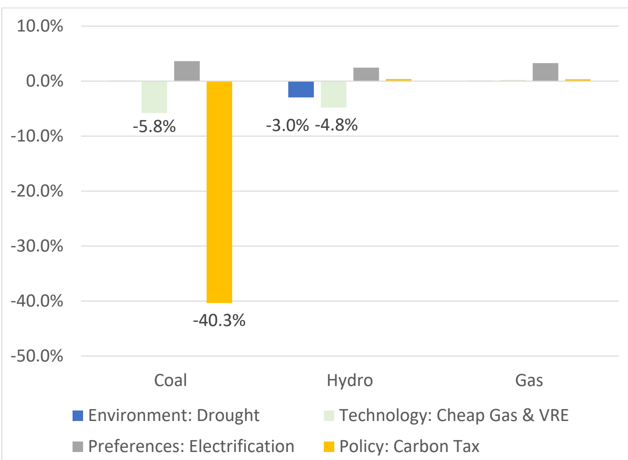

Figure 1: Percent Change in Value of Generation Assets Under Environment & Technology Shocks

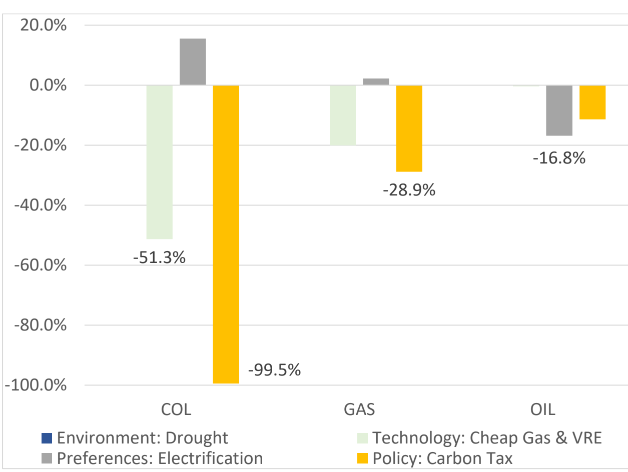

Figure 2: Percent Change in Value of Natural Resource Stocks

Technology

Solar and wind generation costs have declined precipitously over the past decade (IRENA, 2019) and natural gas prices have halved since the mid aughts (EIA, 2019a). The cost of electricity generation from all three is projected to continue improving (EIA, 2019b). Lower than anticipated capital costs for these types of electricity generation will put downward pressure on the asset values of other types of generation. We examine a 20% reduction in the capital costs of variable renewable energy (VRE; i.e., wind and solar) electricity generation coupled with a 20% reduction in the cost of producing natural gas. Coal and hydroelectric generation capital show impairment with declines in value by 5.8% and 4.8% in this scenario (Figure 1). The value decline for coal resources is larger than generating capital at 51% (Figure 2).

Preferences

Electrification of primary energy uses will most likely occur through a mix of changing consumer preferences and lower cost, where we'd consider lower costs the result of technology improvements. Still, a significant component of electric vehicle adoption will depend on consumer preferences and attitudes independent of cost (e.g., Choo and Mokhtarian, 2004). We simulate such a change by shifting 90% of ground transportation and household demand for refined oil products to electricity demand. This would represent a significant increase in total vehicle miles traveled but this stylized approach isolates the substitution and income effects of the preference shift.[3] The value of oil resources declines by 16.8% (Figure 2) in this scenario and generation capital increases slightly for all types (Figure 1).

Policy

A carbon tax is perhaps the most eminent example of climate-related public policy that could impair or strand assets. We impose a carbon tax of $35 per ton of carbon dioxide held constant in real terms with a border carbon adjustment that taxes imports based on their embodied carbon. Given its relative carbon intensity, cost-competitive substitutes, and few alternative uses, we would expect coal stocks to be significantly impaired by such a policy. Figure 2 shows that the carbon tax strands coal stocks with a 99.5% decline in their value. The value of coal generating equipment is significantly impaired with a 40% loss in value suggesting that coal electricity generation remains in the generation mix only by purchasing coal effectively at the price of the carbon tax and accepting a significant write-down in the value of the generating assets

Conclusion

Negative effects associated with climate change continue to increase in intensity and frequency. Mitigating investments and policy changes are becoming more imperative and the need for assessing associated investment risks is growing. The balance of climate change and our responses are escalating the risks of asset impairment associated with changing environment, technology, preferences, and policy. We provided a typology of climate-related impairment causes and highlight the broad range of potential impacts to assets across a set of stylized simulations focused on the energy sector. Examples are numerous in each type of cause and a careful articulation of their nuances and the essential model structures required to effectively capture them is critical.

Leveraging models like ARTIMAS, investors and policy makers can make better-informed decisions that account for these risks. Further research on the nature and extent of stranding risk in these causal types is needed to provide better estimations of the risk facing assets in the face of climate change.

Footnotes

[1] https://www.epa.gov/cira

[2] US EIA, 2017. "Hydroelectric generators are among the United States' oldest power plants." Retrieved from https://www.eia.gov/todayinenergy/detail.php?id=30312

[3] Total transportation demand for motor gasoline was approximately 17 quadrillion BTU (17% of total demand in 2018) or $400 bn. See https://www.eia.gov/outlooks/aeo/data/browser/#/?id=2-AEO2019&cases=ref2019&sourcekey=0. (quantity), https://www.eia.gov/outlooks/aeo/data/browser/#/?id=3-AEO2019&cases=ref2019&sourcekey=0 (price).

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