MARKETING CHALLENGES FOR THE NEXT GENERATION OF NUCLEAR POWER:

HAS DEREGULATION ELIMINATED THE NUCLEAR OPTION?

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Abstract: The purchase of a nuclear plant relies on bank financing and lenders emphasize the quality of the nuclear plant's projected income stream to repay the financing. This is why all previous nuclear plant financings relied on the monopoly status of the purchaser with its legislatively anointed captive market to ensure an adequate income stream.

Today, due to deregulation, electric utilities can't own regulated power plants in two-thirds of the country. In these states, electricity is generated and sold on a competitive basis by Independent Power Producers, end-use customers are free to choose their electric suppliers, and state regulators no longer ensure cost coverage of the nuclear-related risks.

However, policymakers at last year's United Nations COP26 and other environmental forums touted nuclear power as a solution to climate change because it doesn't produce greenhouse gases. Missing is a discussion and analysis of the impact of this deregulation (and its loss of a guaranteed revenue stream) on the ability to obtain financing and, in turn, on the potential size of this market. Thus, deregulation may have eliminated nuclear power as an option to fight climate change. This presentation builds on earlier research by proposing an analysis of survey data regarding two post-deregulation risk factors (long-term price certainty and long-term output quantity certainty) versus the likelihood to obtain financing.

Key Words: *Deregulation, cost-of-service regulation, economic efficiency, power plant financing, nuclear power, public policy*

1. INTRODUCTION

The construction of a nuclear power plant is a major financial commitment. The most recent data on actual construction costs for a 1,000 MW nuclear power plant exceeds ten billion dollars (King, 2017). Long-term financing is relied upon to pay for most of the construction costs and twenty-year financing terms are common (IAEA, 2017; Harmon & Reynolds, 2003; Joyner, 2013; Wealer et al., 2021). Lenders place great weight on the quality of the projected income stream of the nuclear plant to repay the loans (Harmon & Reynolds, 2003; IAEA, 2014; IAEA, 2017). This explains why all previous nuclear power plant financings have relied on the monopoly status of a purchasing utility, with its legislatively anointed captive market, to provide an income stream sufficient to ensure debt coverage, as well as cover nuclear-related risks to the satisfaction of the lenders.

Today, due to electricity deregulation, electric utilities are not permitted to own regulated power plants in about two-thirds of the U.S. market where electricity is generated and sold on a competitive basis by non-utility Independent Power Producers (IPPs) and state regulators no longer ensure cost coverage of the nuclear-related risks (Ward, 2011; White, 1996). Moreover, in many states, end-use customers are able to choose their electricity suppliers (Ward, 2011; White, 1996). However, policymakers at the 2021 United Nations 26th meeting of the Conference of Parties (COP26) and other environmental forums began to establish nuclear power as a solution to climate change because it doesn't produce greenhouse gases (GHG). Overlooked by the policymakers in these environmental discussions, is any consideration and/or analysis of the impact of this electricity deregulation on the ability of nuclear plants to obtain the financing needed for construction and, in turn, on the potential number of nuclear power plants that could help fight climate change.

This paper fills a gap in the literature by: 1) establishing the case that the deregulation of the electric industry has likely eliminated nuclear power as an option to fight climate change in most of the United States, and 2) proposing an analysis that will quantify the impact of this deregulation (specifically the loss of a guaranteed revenue stream) on the ability to obtain the financing needed for construction.

The argument herein is constructed, sequentially and layer by layer, on the technical, economic, regulatory, and marketing issues that systematically build on each other to support the position that deregulation has removed the requisite underlying credit to support the financing of a nuclear plant. This paper builds on an earlier work (Dansky, 1994) by incorporating several decades of newer technical, financial, regulatory, and market information and by proposing an analysis of survey data regarding two post-deregulation risk factors (long-term price certainty and long-term output quantity certainty) versus the likelihood to obtain financing.

Topics of discussion proceed in the following manner:

1. The environmental push behind the many recent news articles promoting nuclear power as a means to reduce GHG.
2. The economic and technical issues as well as the financial risk issues that impose constraints unique to the financing of nuclear power.
3. The ramifications of significant regulatory changes within the electric industry ("deregulation") that affects economic, technical, and financial risk constraints in such a way as to make it very difficult, if not impossible, to obtain the needed financing.
4. The inability to obtain financing impacts the market viability of nuclear power in the United States.

The resulting clash between two conflicting government policies: The Promotion of Economic Efficiency versus the Promotion of Energy Diversity and the impact on jobs creation.

2. CONCEPTUAL DEVELOPMENT

2.1. Climate Change May Open a Window of Opportunity

Many believe that global climate change is a serious threat to the environment and is primarily caused by man-made GHG (Tollefson, 2021). During the past several decades, international attention to this problem has been growing. Between 1992 and 2021, four United Nations (UN) climate agreements were signed, including the Framework Convention, the Kyoto Protocol, the Paris Agreement, and the recent COP26 Agreement (Almer, 2016; Dimitrov, 2016; Tollefson, 2021). Over time, the number of countries signing these agreements has grown, and the quantity reductions for greenhouse gases have become more stringent.

Multiple greenhouse gases are identified by the UN as the cause of climate change, but CO_2 is identified as the largest contributor (Jaforullah & King, 2015; York and McGee, 2017). The largest share of manmade CO_2 (about 87%) comes from the combustion of fossil fuels (Jaforullah and King, 2015; York and McGee, 2017). Of this, the majority of fossil fuel combustion occurs within the internal combustion engines used for transportation and within the combustion turbines and steam boilers used for electric power generation. With respect to transportation, oil is the primary fossil fuel that is consumed, and with respect to electric power generation, coal and natural gas are the primary fossil fuels consumed. Therefore, to meet the CO_2 reductions set forth in the UN agreements, existing electric generation fueled by coal and natural gas needs to be replaced with some other technology that is climate-friendly.

Being climate-friendly does not necessarily translate to "renewables" since many renewable fuels produce GHG. For example, biomass such as wood waste, landfill methane, and farmed algae all contain carbon and thus are unsuitable for reducing CO_2. The challenge, therefore, is to find electric generation technologies that do not emit GHG. Moreover, to add to the challenge, these GHG-free technologies must also be reliable (PJM, 2021) and economic (Zhongyang, 2022).

Since 1990, the installed capacity of nuclear power in the U.S. has declined as retirements of existing plants exceeded the construction of new plants. Many announced new units were canceled and only one location (having two units) started construction within the last three decades. However, the above concern for global climate change has opened a window of opportunity for the construction of new nuclear power plants in the U.S., because nuclear power does not emit GHG. Policymakers at last year's United Nations COP26 conference and other environmental forums have declared nuclear power as one solution to climate change. The European Union has recently announced it will re-label nuclear power as a 'green' energy source and a component of its strategy to meet climate and energy targets for 2030 under the European Green Deal (Gillet, 2022) as well as its COP26 goals. Not surprisingly, since last year's COP26 agreement, there has been a resurgence of news articles promoting nuclear power as a means to reduce GHG.

2.2. Economic and Technical Issues Create Financing Implications

Nuclear power isn't the only technology that could be used to reduce GHG. There are a number of carbon-free electric generation technologies such as geothermal, hydroelectric, tidal, wind, and solar. Each of these has certain limitations and, as such, no one technology appears to have the overall advantage. Geothermal power is limited to locations where the earth's tectonic plates meet, creating fissures in the earth's crust enabling the hot gases to be accessed (Muther, 2022). Tidal power is also limited to certain feasible locations, and also suffers due to its distance to load centers (Wu et al, 2016).

Hydroelectric plants are also limited to specific locations and cause high environmental impact (Cudmore, 2011) such as the effect on existing flora and fauna when a river is transformed into a lake. No new large hydroelectric plants have been able to secure the requisite permits from the Federal Energy Regulatory Commission and the U.S. Environmental Protection Agency for several decades and several hydroelectric plants have recently been taken out of service and decommissioned to re-establish fish migration and spawning (USSD, 2015).

Wind power is limited to locations where the wind is constant (Cudmore, 2011). Also problematic are the protests of visual pollution due to the size and quantity of the wind turbines, and because it's not 'energy dense', the required large number of wind turbines creates land use issues. Solar power has limitations from inclement weather, cannot generate power at night, and suffers from efficiency losses the further its location from the equator (Cudmore, 2011). It also is not 'energy dense' which creates land use issues. Nuclear power has many technical and political issues (Cudmore, 2011) primarily linked to radiation. However, the European Union's re-labeling of nuclear as a 'green' energy source and incorporating it into its strategy to meet its climate targets might act as a precedent for the U.S.

Imposed as a further constraint, those power plants technologies that have a high fixed capital cost (a high per kW cost) and a low variable cost (a low per kWh cost) are only economical serving the baseload demand (the level of demand that is present around the clock). Nuclear power is one of these.

The above characteristic of nuclear power has important financing implications. In order to be cost-competitive, it is necessary that nuclear plants be operated at a high-capacity factor, where capacity factor is defined as the actual annual output in kWh divided by the annual potential output in kWh. Capacity factors of 90+ percent, i.e., baseload operation, are critical if nuclear power is to be cost-competitive. In other words, using the equation for average fixed costs: $AFC = FC/Q$, where FC is the annualized fixed capital costs of the power plant, and Q is the annual output of the power plant (Mankiw, 2015; McConnell et al, 2021), it is, therefore, important to maintain a high Q to keep AFC down because nuclear plant fixed costs are high (EIA, 2017; King, 2017). By operating as a baseload unit, the high fixed costs of a nuclear plant can be allocated over a greater quantity of kilowatt-hours to minimize AFC.

This also means that nuclear plants cannot be dispatchable (IAEA, 2009), that is, to increase and decrease output during the course of a day to meet changes in electric demand. They can't be used as an intermediate or peaking unit (IAEA, 2009), because this would lower Q and, in turn, increase AFC.

The conundrum is that the price (P) of the generated power must be low enough to ensure that the plant will be called on (dispatch) to sell a high quantity (Q) of the plant's output, and thus be a baseload unit, yet the total revenue (TR = P x Q) must be large enough to cover all costs, including the plant's high capital costs. This is a tight operating window and the nuclear plant must be able to satisfy this constraint over the plant's life despite changes in competing technologies, regulations, and customer demand. The banks that lend money to the owners of the nuclear plant to finance its construction seek to have this operating risk minimized.

2.3. Project Risks That Affect Financing

All aspects of any new power project have risks, whether technical, engineering, social, political, or regulatory. These risks all have the potential to impact a project's long-term profitability, and thus a potential impact on the bank lenders. As such, "all risk is financial risk" (IAEA, 2017: p.11). The key, then, to obtaining financing is to provide the lenders with enough assurance ("belts and suspenders") that the forecasted revenues will always be sufficient to meet the risk-return requirements of the lenders (IAEA, 2017).

The first major long-term risk that gives lenders concern is long-term price certainty. To reduce this risk the power plant must sell its output at a price that is high enough to cover both its fixed and variable costs. A long-term concern is the presence or innovation of competing technologies that are able to sell electricity at a lower price and push the nuclear plant out of the market (Harmon and Reynolds, 2003; IAEA, 2014; IAEA, 2017).

The second major risk is long-term output quantity risk. On one hand, this can come about because the plant is unable to generate power at full output for technical reasons (e.g., the need for many nuclear plants to plug leaking steam generator tubes, which reduces output). However, this risk can also come about because a lower costing competing technology can push the nuclear plant "up the dispatch curve" and block it from being a baseload plant (and thus reduce Q). This will result in a shortfall of total revenue (Harmon and Reynolds, 2003; IAEA, 2014; IAEA, 2017), and in turn, affect the ability to make payments to the lenders.

The lenders are also concerned about the risks of cost uncertainty (IAEA, 2017; Joyner, 2013). Construction cost overruns translate into increased annual fixed costs, affect debt coverage ratios, and impact debt ratings (Wealer et al, 2021; Ziegler and Dansky, 1982). All nuclear plants constructed in the U.S. to date experienced significant construction cost overruns, sometimes doubling and tripling the initial cost projections (Frye, 2008). The Shoreham nuclear plant experienced a quintupling in cost before being terminated (Ross and Staw, 1993). Thus, the history of nuclear power is that cost overruns are more common than not and this affects the degree of risk as seen by the lenders.

Construction schedule delays affect cash flow, affect the start of debt repayment, and increase the interest on the debt during construction (Wealer et al, 2021). Referred to as Allowance for Funds Used During Construction, or AFUDC, this is the accrued interest on the loans during construction that is capitalized and converted into a fixed cost to be repaid with interest to the lenders (Wealer et al, 2021; Ziegler and Dansky, 1982). Given the 8–12-year construction schedule for a nuclear plant, it is common that the compounding interest of AFUDC doubles the cost of a nuclear plant (Ziegler and Dansky, 1982).

Another major risk of concern to lenders is the cost and availability of insurance. Commercial insurance companies have not been willing to insure nuclear risk, and as such, the federal government instituted, under the Price Anderson Act, federal insurance guarantees limiting the risk exposure of nuclear plant owners and their insurers (Fishman, 2018; Kolomitz, 2016). Congress has extended the Price Anderson Act several times (Fishman, 2018; Kolomitz, 2016), but it is unknown if they will continue to extend this protection, or if they will extend it to non-utility IPPs.

Finally, there is the risk associated with the cost of decommissioning and decontaminating a nuclear power plant at the end of its useful life, and the cost and availability of spent fuel storage (Bems et al, 2015; IAEA, 1997). A permanent solution for spent fuel storage has yet to be approved in the U.S. due to political considerations and is thus difficult to quantify. Together, each of these poses a significant risk to the lenders, which in the past have been addressed to the lenders' satisfaction under a regulated monopoly utility cost-of-service framework (Grantham, 2017; Harmon and Reynolds, 2003). Under this framework, known as the "sovereign method of financing" (IAEA, 2014), the government assumes the revenue and cost risks or it sets forth regulations that require these risks to be assumed by captive customers.

Specifically, in the United States, these long-established cost-of-service regulations go back to the Supreme Court decision in Hope Natural Gas v. Federal Power Commission (FPC) and established the "used and useful" doctrine for regulated monopoly utilities (Brown, 1944; Cabot, 1929). Under this doctrine, if a power plant (or any utility asset) has been determined by the appropriate regulatory body to be used and useful, then the prudently incurred costs, including cost overruns, schedule delays, and interest during construction, plus a reasonable rate of return, shall be included in the electric rates charged to customers (Brown, 1944; Cabot, 1929). Moreover, the utility's retail customers situated within the geographic boundaries of the utility's service territory are captive—they can't switch electric providers no matter how high the electric rates that have been approved by the regulators. These captive customers provided the ultimate credit support for the utility's construction plans. Thus, under a regulated monopoly utility framework, the revenue and cost risks, *such as ensuring baseload operation to maintain a high Q and lower AFC*, were reduced to a point sufficient to satisfy the lenders.

This regulatory framework supported the construction of 91.5 GW of nuclear capacity in the U.S. during the 1960-1990 timeframe (Kumar, 2021). In round numbers, this is about 90 nuclear units. Very little was started after 1990 (only Vogtle Units 3 and 4 which are now under construction) (Kumar, 2021). Some of this post-1990 drought may be attributable to the 1978 Three Mile Island, 1986 Chernobyl, and 2011 Fukashima nuclear accidents, some of it may be attributable to newer lower-costing generation technologies (EIA, 2017), and some of it may be due to significant regulatory changes within the electric industry ("deregulation") affecting the ability to obtain the needed financing, which is the primary focus of this paper.

Despite the post-1990 nuclear construction drought in the U.S., many other countries continued to construct nuclear plants (Kumar, 2021). The sovereign method of financing also holds true for the rest of the world; in some countries, the government agreed to assume the revenue and cost risks, and in others, it passed the risks on to captive customers (IAEA, 2014; IAEA, 2017). No nuclear power plant has successfully secured financing anywhere in the world without some form of the sovereign method (IAEA, 2014; IAEA, 2017). Other forms of credit support have been explored (IAEA, 2014) but none have successfully resulted in the financing of a nuclear plant. These other forms of financing, including project financing and balance sheet financing, are used routinely to finance coal, natural gas, wind, and solar projects, all of which have different risk profiles from nuclear plants (Dansky, 1994; IAEA, 2014; IAEA, 2017).

2.4. Electric Deregulation Eliminated Cost-Of-Service Rate Regulation

The above "used and useful" regulatory framework served the participants of the electricity industry well from 1920 to 1970 when there was a long-term general decrease in electricity rates largely due to technology improvements in fossil-fuel steam-generation thermal efficiency (Isser, 2003). In the 1970s, however, inflationary pressures began to drive up electricity prices, the Clean Air Act imposed additional costs on fossil-fired plants, and the OPEC oil embargoes in 1973 and 1978 impacted oil prices (Isser, 2003). In addition, cost overruns on the roughly 90 nuclear units, which occurred under the monopoly utility cost-of-service regulations noted previously, put upward pressure on electricity prices. The term "rate shock" was coined at this time, due to the increase in rates caused by high nuclear plant costs, and was indicative of the widespread concern of the public (Barber, 1986; EUN, 1984).

Simultaneous with this increase in nuclear plant costs, new technology became available, primarily in the form of natural gas combined-cycle units. This new technology had several advantages: lower capital costs, efficient heat rates at smaller scales, modularity of design and construction, load-following dispatch capability, and a risk profile that did not depend on cost-of-service regulation to secure financing (Dansky, 1994; EIA, 2017; Olkhovski et al., 2021).

The combination of increasing electricity prices and the availability of smaller-scale new technology captured the attention of economists that had witnessed and/or participated in the deregulation of the airline, package delivery, and trucking industries. To many economists (including one of the authors of this paper), the risks of regulatory failure, as specifically observed in the lack of economic incentives to curb power plant cost overruns, were greater than the risks of any market failure that might arise from a market that was oligopolistic and not fully competitive, or arise from an oligopolistic market that had significant, but different, regulatory impositions (Isser, 2003). This resulted in a concerted push to deregulate the electric power industry, and these efforts were primarily aimed at dissolving the long-standing vertical integration of generation, distribution, and retail sales.

Congress responded to this push with the Public Utility Regulatory Policies Act of 1978 (PURPA); the first in a series of federal actions to encourage competition and increase economic efficiencies in the electric generation market (Joskow, 1989; White, 1996). PURPA directed state regulators to determine state-specific rules for electricity pricing based on marginal cost prices. See Dansky (1987) for a summary of several marginal cost price formats that emerged from several state hearings.

Other legislation followed to further encourage competition including the Energy Policy Act of 1992 (EPA) which made changes to both the Public Utility Holding Company Act of 1935 (PUHCA) and the Federal Power Act of 1935 (FPA) (Flores-Espino et al., 2016). After the passage of PURPA and the EPA, most states enacted legislation to deregulate both the generation of electricity and the retail sales of electricity (Dansky, 1994). The Federal Energy Regulatory Commission (FERC) then issued orders 888 and 1000 to further promote economic efficiencies arising from competition in electric markets by providing open access to electric transmission lines (Isser, 2003).

Arising from this string of legal and regulatory changes was a restructured electricity market serving most of the United States. In this restructured market, electric utilities were required to divest their electric generating assets. Most electric plants are now developed, owned, and operated by non-utility IPPs, and in approximately two-thirds of the U.S. market, these IPPs sell their electricity into a competitive wholesale "electric grid" as a commodity using prices provided by the IPP to the grid operator the day prior (Ward, 2011; White, 1996). Thus, prices change daily and there is no price certainty.

Cost-of-service regulations are not available to these IPPs. They make use of project financing and balance sheet financing the same as other competitive businesses in other markets. They survive, or not, on their ability to make a return on investment in a competitive market the same as other competitive businesses in other markets. In short, the goal of economists several decades ago to deregulate and restructure the electric generation market, and bring economic efficiencies through competition, has largely succeeded. Numerous studies (Csereklyei & Stern, 2018; Fabrizio et al., 2007; GAO, 2002; Lei et al., 2017; Musco, 2017; Switzer & Straub, 2005) have shown that deregulation led to increases in operating performance and plant efficiency, as well as lower electricity prices to customers. Whether this deregulated environment can be habitable to new nuclear power plants is unknown.

2.5. Impact of Deregulation on New Nuclear Power Plants

Today, the regulatory structure affecting the construction of new power plants is divided. In two-thirds of the U.S., the role of the regulated utility is now limited to distributing the electricity generated by the non-utility IPPs (Ward, 2011; White, 1996). In the other one-third of the country, regulated utilities can continue to own regulated electric power plants because these states never enacted the federal regulations to deregulate (Electric Choice, 2021; Flores-Espino et al., 2016) due to countervailing political pressures.

Consequently, in two-thirds of the United States: a) there are competitive wholesale and retail electricity markets (White, 1996), b) there are no regulated monopolies for the generation of electricity (Flores-Espino et al., 2016), c) the previously captive retail customers are now free to choose their electric suppliers (Flores-Espino et al., 2016), and d) the revenue and cost certainty that the lenders previously relied upon via the "used and useful" doctrine have been eliminated (Dansky, 2002; Ward, 2011). While nuclear power remains potentially financeable in the one-third of the U.S. market that remains regulated, the underlying basis for the financing of nuclear plants (the sovereign method of financing) has been removed in two-thirds of the market (Dansky, 1994). This lack of long-term revenue and cost certainty in two-thirds of the U.S. market suggests that nuclear power plants are unlikely to obtain financing within most of the U.S. market (Dansky, 1994). It is this two-thirds of the market that is the focus of this paper.

2.6. Implications

Policymakers at the 2021 COP26 meeting and other recent environmental forums have offered nuclear power as one solution to climate change, however, none of them have publicly recognized the likely inability to secure financing in most of the U.S. as an impediment to meeting GHG reductions. The "real obstacle [to building a nuclear plant] isn't the Sierra Club but the … analysts on Wall Street" (Aston, 2006:1). Standard & Poor's Rating Service stated that any electric utility that pursued a new nuclear plant would have its credit rating negatively impacted (Frye, 2008). The CEO of a large electric utility with prior nuclear experience stated the credit rating agencies "would assuredly drop your bonds to junk status" (Frye, 2008:351), and Moody's Investors Service dropped the bond rating of SCANA (the parent company of a utility) when the company announced it was considering construction of a new nuclear power plant (Frye, 2008).

While this is suggestive of a financing problem, it is hardly conclusive. More analysis is needed. To that end, this paper fills a gap in the literature by: 1) establishing the case that the deregulation of the electric industry has likely eliminated nuclear power as an option to fight climate change in most of the United States, and 2) proposing an analysis that will quantify the impact of this deregulation (such as the loss of a guaranteed revenue stream) on the ability to obtain financing and, in turn, on the potential size of this market.

2.6.1 Conflicting Public Policy of Economic Efficiency Vs Energy Diversity

If the results of this proposed analysis suggest that the financing of nuclear power in deregulated jurisdictions is not feasible, we are then presented with a clash of conflicting public policies. On one hand, the government has promoted economic efficiency whenever possible, including but not limited to the deregulation of the airline, trucking, package shipping, natural gas, and electric industries. It has busted trusts and pried apart monopolies since the 1890 passage of the Sherman Ant-Trust Act in the name of increased competition. In that vein, the 'invisible guiding hand' of competitive markets should decide what type of GHG-free generation should be built.

On the other hand, the government has promoted energy diversity, and expended billions of dollars in energy R&D, as a means to reduce market risk and enhance energy security (National Research Council, 2007). From this perspective, if nuclear power is unable to obtain financing in a competitive market, the government could carve out a protected regulated niche (a non-compete market set-aside) for nuclear power even though it would be at the expense of economic efficiency with ratepayers taking on the revenue and cost risks. But there may not be a need to carve out a protected niche for nuclear power to promote energy diversity since there are other existing GHG-free generating sources previously discussed including wind, solar, hydro, tidal, and geothermal, and other possibilities on the horizon such as hydrogen-fueled combustion. However, another important issue distinct from GHG reduction emerges from this discussion – the impact on jobs.

Each GW of nuclear power (the size of a typical nuclear plant) creates several thousands more middle-class construction jobs over a longer period of time than the alternatives (DOE, 2022; NEI, 2022). For example, there are presently 9,000 construction workers at the under-construction Vogtle nuclear plant (DOE, 2022) which is expected to take ten years to construct (King, 2017). In contrast, a wind or solar project of the same GW size would create between 500 and 800 construction jobs over a three-year period (Wyoming, 2019). Thus, there is a significant difference in the creation of construction jobs between nuclear and other technologies.

This back-and-forth between Promoting Economic Efficiency vs. Promoting Energy Diversity then filters down to one question: Is it in the public interest -- a concept recognized as rife with complex and diverse multiple definitions (Dadashpoor & Sheydayi, 2021) -- to have electric customers pay more for electricity (i.e., remove competition and reinstate cost-of-service regulation to make nuclear financeable) to create more construction jobs? Elected officials would be able to create these jobs via an indirect tax on the public (higher electric rates) that would be off the government's budget and hidden from budget analysts. This approach to funding government-supported programs is not uncommon due to electricity's inelasticity of demand (Mankiw, 2015; McConnell et al., 2021). For example, taxes and surcharges that fund government programs account for 25-30% of one utility's bills in New York (Sanderson, 2014) and the State of New Jersey mandates a Societal Benefits Charge on every electric bill to fund efficiency grants and loans, renewable power subsidies, education, and assistance to low-income electric users (NJPRO, 2010). Thus, intentionally increasing electric rates to fund more construction jobs is not without precedent.

While timely and salient, this sidebar into deregulation's impact on power plant construction jobs will be the focus of future research. Given that establishing the availability of financing is a requisite first step, the primary focus of this paper is the impact of deregulation on nuclear plant financing to which we now return.

2.7. Propositions

P1: Assuming that all other risks are held constant, lending banks are unlikely to provide nuclear power plant financing without long-term price certainty (i.e., the price per kWh received by the nuclear plant will remain high enough to cover fixed and variable expenses including debt coverage).

P2: Assuming that all other risks are held constant, lending banks are unlikely to provide nuclear power plant financing without long-term output quantity certainty (i.e., the price per kWh charged by the plant will remain low enough to ensure baseload operation (high Q to maintain low AFC)).

P3: Assuming that all other risks are held constant, lending banks are unlikely to provide nuclear power plant financing without long-term revenue certainty (i.e., the price per kWh times the output quantity will remain sufficient to cover fixed and variable expenses including debt coverage).

3. PROPOSED METHODOLOGY

3.1. Design and Sample

The research methodology entails a survey questionnaire from a population of 30 lending bank executives. A priori, a larger sample size would be preferred, but there are only several dozen banks in the world that provide financing for power plants in the U.S. Because of the complex and very specific nature of power plant financing, it is necessary that the data be collected from those bank executives that previously financed electric generation projects, are familiar with electricity deregulation, and are familiar with the financing risks of the electric industry so as to reduce sampling error (Bansal, 2017). Moreover, the use of multiple responses from co-workers at the same bank, who usually work together in a small team on each power plant financing, may affect the independence of each data point. Thus, this study faces a data collection challenge which is addressed below.

The sample population noted above is expected to be sufficient to provide statistical significance on a t-test, but it may not be sufficient for multivariate regression analysis. Second, it is possible that there will be a strong correlation between the two independent variables, price and quantity. In a post-deregulation environment, the daily price submitted by the power plant owner to the grid operator determines where the plant falls on the dispatch curve, and thus, the quantity sold may be a function of price. If there is a strong correlation, then a multivariate analysis may not be warranted. Therefore, the survey questions will be designed to enable a switch from multivariate regression analysis to a paired one-tailed t-test if necessary. The proposed analysis addresses a specific real-world application that should be useful to financial lenders, power plant owners, manufacturers and constructors of nuclear plants, and government policymakers and represents a market that may reasonably reach a hundred billion dollars.

3.2. Manipulated Variables

Each respondent will view four scenarios that manipulate the perceived certainty of the nuclear power plant revenues (price and quantity) across conditions and measure their willingness to provide financing, as depicted below. This scenario-based experimental design is widely accepted (e.g., Grewal et al. 2008; Baranishyn, et al., 2010)

Table 1 Experimental Conditions

No price certainty/No quantity certainty	Price certainty/No quantity certainty
No Price certainty/Quantity certainty	Price certainty/ Quantity certainty

To that end, each respondent will answer a series of questions that are identical in all respects except for a change in the certainty of each independent variable (long-term price certainty (X_1) and long-term output quantity certainty (X_2). The dependent variable will be the banker's willingness to finance a nuclear plant under each scenario. Manipulation checks for X_1 and X_2 will be utilized along with X_1X_2 as this represents revenue. Within each scenario, other factors will be held constant, identical in all matters that materially impact the revenue and cost of a power plant, including the size of the nuclear power plant, technology, design, construction method, location, permitting, and environmental matters, (IAEA, 2009; IAEA, 2017; Ziegler & Dansky, 1982). Thus, the four scenarios have identical risk profiles except that they vary in their revenue (price and/or output quantity) certainty. Scenario #1 presents the base case with low price risk and low output quantity risk. Scenario #2 presents controlled output quantity, with an unknown price (high price certainty risk). Scenario #3, presents controlled price with an unknown quantity (high output quantity certainty risk). Scenario #4, presents uncontrolled price and output quantity (high price certainty risk and high output quantity certainty risk).

Scenario #1 reflects the "sovereign method of financing" and, as previously discussed, this scenario supported the financing of every nuclear plant presently constructed. Meanwhile, scenarios #2-4 reflect actual non-nuclear IPP projects that have successfully obtained financing. Thus, the above manipulations in the survey questions possess ecological validity.

Responses to the various scenarios will be scored on a 7-point Likert scale ranging from "Not Willing" to "Willing". The data will be used to determine a two-variable regression analysis of the form:

$$\mathbf{y = b_0 + b_1x_1 + b_2x_2 + b_3x_1x_2 + e}$$

Each regression coefficient is a slope estimate. With more than one independent variable, the slopes refer to the expected change in y when x makes a unit change while keeping all other variables constant (ceteris paribus). Therefore, b1 is the change in y given a unit change in x1 while holding x2 constant, and b2 is the change in y given a unit change in x2 while holding x1 constant.

If a two-variable regression analysis cannot be performed due to the data problems noted above, the data will be analyzed using a paired one-tailed t-test to determine if statistically significant differences exist between the pre-and post-deregulation scenarios (certainty and no certainty, respectively) for both independent variables individually.

Here, survey responses for each paired question are anticipated to form two normal distributions with the mean of the "post-deregulation" (no certainty) scenario resting leftward of the "pre-deregulation" (certainty) mean. That is, the anticipated results will show a reduction in the likelihood of a bank providing nuclear plant financing in the post-deregulation environment. It can also be interpreted as a comparison of the likelihood of a bank providing nuclear plant financing within those states that deregulated their electricity markets versus those states that continue to use monopoly utility cost-of-service regulation.

4. STUDY LIMITATIONS

Scenarios by their nature require respondents to imagine how they would react to stimuli that has been presented in a controlled format and therefore real-life reactions may have more variability. However, this also provides a more challenging context to find support for our propositions, while raising internal validity and control through the clean (isolation) manipulation of our independent variables. Also, the proposed analysis investigates the risks associated with revenue certainty and is therefore limited in that it does not address the risks associated with cost certainty.

5. FUTURE ANALYSES

Due to the limitation noted above regarding cost certainty, future analyses are proposed to analyze the willingness of banks to provide financing as a function of Construction Cost Overruns, Construction Schedule Delays, Interest During Construction/AFUDC, Decommissioning and Spent Fuel Storage, and Insurance/Price Anderson Act availability. Furthermore, two Canadian provinces (Alberta and Ontario), as well as Great Britain, have deregulated their electricity markets along lines generally similar to the U.S. Future analyses can be extended to include these markets, with attention paid to regional specifics.

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