GAINS FROM ENERGY TRANSITION GAPS: ADAPTIVE MOVES TO WINNING STRATEGY

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Abstract

Financial economics optimizes value by reducing deviations (or risks) from expected outcomes (or returns). It errs when managerial aversions or preferences, volatilities, and prior commitments are ignored. To profit from transitioning energy markets, managers need to explicitly evaluate the returns impact of rivalries, pacing, and the interacting portfolio effects. In this paper, we evaluate how geocentric resources (i.e. hydro and geothermal) differ in their strategic endowments from those involving the harvesting of disperse energy (i.e. wind, solar, and photovoltaic). Under dynamic markets, asymmetric costs facilitate portfolio benefits through diversification, and switching options when there is managerial flexibility. Geocentric resources confer early mover's advantage by locking out rivals, while encouraging managers at act now to avoid incurring high deferral costs. Counter-intuitively, for solar and photovoltaic, the opposite is the case for two reasons: Low output reduces the foregone returns. Rapid asset costs decline offer the prospect of substantial savings on future capex. Combined, managerial inaction enhances portfolio value and competitiveness. Strategically, for fossil fuel supply portfolios, value is optimized under unconstrained markets by first diversifying with geocentric resources. Wind could follow, with photovoltaic and solar (and possibly battery storage) as later stage options.

Keywords: *Deferral value; energy transitions; early-mover's advantage; late-mover's benefits*

INTRODUCTION

A transition to low carbon energy markets, as previous transitions demonstrated, is likely to be tentative and recursive (Smil, 2010). This would imply continual reconfiguration of network relations and benefits, where managers respond by rearranging their resources, competitive approaches, and adaptive capabilities (Breschi et al, 2000). To prosper, managers would need to adapt continually, informed by deep analysis and understanding of an evolving landscape (Rumelt, 2011).

Corporate finance practice, and their prescribed solutions, are ill equipped to address these managerial challenges. Capital budgeting's static view that rewards predictable returns, is disconnected against the backdrop of the inherent volatilities of dynamic markets. The resulting gaps give rise to ignored risks, or unexploited opportunities.

"Act fast" is synonymous to "decisive actions", advocates would claim. Within the managerial world, gaining "first-mover's advantage is often unquestioned (VanderWerf, et al, 1997; Kerin, et al, 1992). When a "bias for actions" persist, the transition to low carbon economies alternates between "altruistic exuberance" and "cautious indecision".

The causes and prescriptions are plenty. The diagnoses often err when opinions, respected as they may be, are used as evidence (or "facts") to inform investment decisions. Here's how:

Slow progress to decarbonization is ascribed to inaction by politicians (UN, 2018). Germany's *Energiewende* experiment proved painful, financially and socially, albeit described diplomatically as unique and unlikely to be replicable (Cunningham et al, 2018). Business' "lukewarm response" (as UN claims) and bureaucracy's paralysis elicit calls to push for temporary shutdown of democracy because it moves too slowly to effectively address the climate challenges (Fischer, 2017). However, far from a consensus, the ideological divide is sharpened within the American public (Pew, 2014), and among climate solutions proponents (Newman, 2015).

Policy's disconnect with managerial decision-making under uncertainties opens gaps that could mis-perceive investments' value. This arises when policy advocates actions on what they hold dear. Managers, in contrast, consider such aspirations, whatever they happen to be, as too distant to merit immediate commitments. Climate change initiatives are among such advocacy. Ironically for managers, after failing to meet more modest targets, policy calls for aggressive CO_2 emissions cuts using broadly similar approaches that were previously employed.

Managers' lukewarm response is expected: Bearing the gargantuan costs, without a clear sight on payoffs that they can appropriate, few managers would risk capital for policy's greater glory. Hence, notwithstanding public expressions of intent, the conversion of aspirations to actions are more tentative.

To reverse this deadlock, managers and policy would need to reframe the dialogue. We posit that, for private capital to play a meaningful role, investments will have to be undertaken with an eye on uncertain strategic and market contexts. Instead of assuming away volatilities, managers and policy would benefit from explicitly evaluating these factors:

- The firm’s initial endowments, strategic and operational flexibility (Dixit and Pindyck, 1994), the managers’ appetite for risks (Thaler, 2015), and how it impacts managerial decisions, are of paramount importance. Embedding this thinking when formulating the firm’s strategic moves are more likely to sustain competitive advantage.

- This contrasts with capital budgeting’s well-ordered value hierarchy (Graham and Harvey, 2001), that falls into disarray at the first encounter with volatile markets. Paradoxically, when managers attempt to re-assert returns predictability, through a web of rigid obligations (as in *take-or-pay* contracts) (Masten and Crocker, 1985), risks increase from continual renegotiations. In addition, when prior decisions and commitments are ignored (e.g. *sunk costs*), managers tend to err in their investment choices that could perpetuate corporate under-performance (Chevalier-Roignant and Trigeorgis, 2011).

In this “unpredictable” world, to succeed financially, managers would have to act adaptively. To respond effectively, managers would deploy and harness the resources within their portfolios (Sharpe, 2007). Acting with flexibility contrasts with NPV’s (or net present value) myopic view, a thinking that shapes practitioners’ accepted wisdom (and beliefs).

Policy is not immune to NPV’s allure that is asserted through social costs-benefits analysis, and its similarly static world view. For this reason, policy tends to see transitions as a unidirectional (often rigid) path towards achieving a low carbon ideal. However, as recursive energy transitions deviate from policy’s prescribed path, gaps in prices, volumes, or costs, emerge that alter the firms’ sources of competitive advantage.

Policy’s rigidities create arbitrage when managers, under flexibility conditions, could exercise their options to supply or exit. By doing so, managers gain by avoiding losses, or appropriating excess returns from higher than expected prices (or volumes).

To respond to uncertainties, managers select and operate their portfolios by strategically pacing, or restructuring, their investments. They may choose to adapt according to how technologies evolve asymmetrically according to how learning effects vary, or returns differ. Specifically:

1. Resource geo-centricity locks-in unique access to profitable niches to confer early-mover’s advantage (e.g. hydro, geothermal, or wind);

2. Learning effects trade off foregone returns against capex saved from deferral, where rapid asset cost (or capex) declines confer late-mover’s benefits (e.g. thermal solar, or Solar, and photovoltaic, or PV).

These observed phenomena question NPV's *now or never* decision rule (Copeland, et al, 2000). Adaptive moves offer managers the choice to "act fast" to lock in first-mover advantages, or "move slow" with prudence to reap late-mover's benefits. "Acting fast" tends to yield sustained advantages that accrue to geocentric resources. Such advantages are reinforced by secure concessions, cost effective investment execution, successful geothermal exploration, or early entries for hydro.

Learning effects reduce asset costs as more are installed, so the theory says (MacDonald, et al, 2001). Since 2008, improved technologies and enhanced efficiency, are making onshore wind, and increasingly offshore wind, cost competitive. Consequently, the decision is evenly balanced between investing now, or deferring.

In contrast, Solar and PV's experience argue for "moving slow". The pace of decline in its asset costs, compounded by supply gluts, exceeds the predicted rates (Hook, et al, 2018). As a result, the capex savings significantly exceed any foregone returns on deferral.

In the sections that follow, the theory behind the analytical framework is presented. We then simulate the conditions under which first-mover advantage could arise, and how managers could lock-in its portfolio premium. We then examine the deferral value to inform managers when to "act fast", or "move slow". We conclude and offer reflections on how managers could reframe their strategic approaches.

LITERATURE AND ANALYTICAL FRAMEWORK

Capital budgeting manifests its influence on investment evaluation through the application of NPV (Graham and Harvey, 2001). To optimize value, cash flows should be predictable which is achieved usually through long term *take-or-pay* obligations with rigid volumes and prices (Masten and Crocker, 1985). This comes at the expense of foregoing flexibility, the implicit costs of which are ignored to the detriment of the firm's financial performance (Dixit and Pindyck, 1994).

The long-term viability of competing firms depends on their prior choices of power generation technologies. This arises from how the chosen technologies influence costs and supply availability, and how credible the regulator was in setting and implementing the rules (Cameron, 2005). Faced with these "stable" parameters, and the absence of significant interactions among competing supplies, the firm is treated as the sum of the parts (e.g. sum of individual projects).

Market deregulation in the 1990s disrupted the firms' managed existence. With the introduction of a wholesale power market, power prices are set periodically by marginal supply (e.g. a price-setting supply) as a function of prevailing supply and demand. This development forces managers to contend with how they respond to uncertainty surrounding volatile power prices, fuel costs, and volumes.

Managers come to experience the limitations of *take-or-pay* contracts. Over time, as contracting parties reneged or renegotiated their take-or-pay contracts, managers move to actively manage the effects of volatilities on their payoffs.

Decisions to supply are now subject to achieving a positive margin between periodic power prices and their costs of supply. The ability to interrupt supplies to avoid losses represents the value of flexibility. This contrasts with conventional logic that considers interruptible supplies as posing uncertain payoffs. NPVs penalized such investments with higher discount rates, hence reducing the present value of the payoffs.

European power utilities longed for the payoffs stability that the regulated system provided. They followed a strategy of indexing their costs to the marginal supply (usually ACCGT, or advance combined cycle gas turbines). With fuel and operating costs shadowing those of the marginal supplies from ACCGTs, payoffs became a constant (or equivalent to the recovery of fixed asset costs). Inadvertently, ACCGTs became the favored technology source that eventually dominated deregulated European markets. In competitive terms, power utilities came to choose similar technologies (symmetric choices) with what their peers were opting (which was often ACCGTs).

The emergence of renewables poses a different managerial challenge. Renewables offer firms the opportunity to fully diversify their portfolio by combining oil or gas-correlated supplies (e.g. Coal and ACCGT) with renewables. Beyond the obvious benefits of experiencing costs diversification, the flexibility to switch from fossil fuels to renewables (subject to availability and prices) provided a valuable switching option.

The real evidence of how renewables change the *game* lies in how the firms' financial performance differs according to their choice of technologies, or its mix within a supply portfolio.

The decision to adopt renewables or not would depend beyond the fixed and sunk costs of investment. It includes the effects from technological discontinuity and transaction costs that can rarely be isolated, or allocated to individual firms (Tsoutsous and Stamboulis, 2005). Managers needed to understand how market structures and competitors' actions influence their financial performance. This becomes a fundamental driver in informing the firm's technology choice decisions.

At this point, the desire for predictable returns clashed with the power market's changed realities. In the world of stable payoffs, sunk costs from prior commitments have no influence on project outcomes. Under our portfolio logic, we accounted for such prior commitments as the initial endowment. By making their effects explicit to a portfolio's performance, the diversity of actions that renewables provide has far-reaching implications to non-cooperative competition. In spite of its evident impact on the firms' performance, managers usually assumed away their effects under NPVs (Graham and Harvey, 2001).

Firms could exploit the technologies' operating cost differentials, supplies that are variable (for wind and solar) or modulated to demand (for coal, gas, hydro and geothermal), varied capital expenditures, and differences in times to build. With these interactions, the outcomes became dependent on the actions that the firm took in the past and how competitors responded to these actions (Walsh, 2012). How the firm deals with the interacting effects of diverse technologies and competitors' actions now have to be faced, and evaluated explicitly.

In the face of uncertainty, how does managerial flexibility add value, and how can these values be estimated? Moreover, when rival firms' actions can alter volumes, prices and costs of supplies, how can the effects of these actions be incorporated in managerial decision-making by every firm?

The first aspect is the domain of real options theory, where the value of flexibility is evaluated using a binomial tree analysis (Rubinstein, 1994; Dixit and Pindyck, 1994). Energy investments, in the face of uncertainty, tend to be large and impact future supplies and prices. For this reason, the value of an investment is contingent upon what actions competing firms might take. This second consideration is appropriately examined by employing game theory. Game theory was developed for predicting the effects of competitor's actions, although in the face of uncertainty the value of flexibility is hardly considered (Chevalier-Roignant and Trigeorgis, 2011).

Han Smit and Lenos Trigeorgis (2004) suggested a way around this problem using "option games", a combination of real options and games theoretic logics. They overlay real option's binomial tree analysis to account for flexibility value onto two-by-two payoffs matrix of games.

How this informs managerial decision-making is addressed in the subsequent sections. What becomes apparent are outcomes that are counter-intuitive to what managers would expect from NPV. Our analysis offers feasible pathways, by employing a portfolio of supplies, to reframe NPV's "risk-avoidance" bias. As a result, managers could identify unexploited and ignored opportunities.

RENEWABLES INITIAL ONSLAUGHT: GEOCENTRIC RESOURCES

Energy systems tend to fall under one of these supplies categories: a) Heavy reliance on coal or gas; b) predominance of hydro or geothermal; or c) hybrid of fossil fuels and renewables. Energy markets tend to operate under duopoly or competitive conditions, with a few monopolies surviving the onslaught of deregulation. Geographically, systems may be contiguous and largely interconnected (Europe of United States), or archipelagic and fragmented (Philippines or Indonesia). This paper focuses on the former, while the lessons are applicable to larger segments of archipelagic systems, such as Java in Indonesia, or Luzon in the Philippines.

Fossil fuels tend to offer supplies that are modulated according to how demand varies, while exhibiting volatile fuel costs. In contrast, hydro and geothermal tend to cost more to build (when compared to gas) but enjoys zero fuel costs. Wind, PV, and Solar enjoy similar zero fuel costs advantage, but exhibit volume intermittency and lower energy conversion rates when compared to geothermal (Geo) or stored hydro (StoHydro).

Under diversifying portfolios, with coal (Coal) or gas (ACCGT) as the initial supply endowments, exclusion of renewables (particularly StoHydro and Geo) could prove financially risky for firms. Operating within dynamic wholesale energy markets, volumes and prices interact that tend to erode power prices (Hirth, 2013; Botterud et al, 2007), as "cheaper" marginal cash costs StoHydro and Geo displace the "expensive" Coal or ACCGT supplies. The "new" price-setting marginal supply would have lower costs, hence reducing market clearing prices.

To illustrate, let us now consider two firms: GasCo and CoalCo. By diversifying into geothermal or hydro, we examine how their strategic economic payoffs (SPO_e) could be altered relative to "gas-only" or "coal-only" portfolios. Uncertain SPO_es are calculated using binomial trees to explicitly evaluate the effects of volume and price volatilities, when there is managerial flexibility. The capital spending, or exercise price, is deducted from the risk-adjusted payoffs to estimate SPO_es. We infer intuitively these strategic insights:

1. *Complementation* provides physical hedges against power price and volume volatilities, when zero fuel costs renewables expands cash margins when power prices are high, while offsetting low prices with higher volumes.

2. *Pricing or volume flexibility* allows residual supplies, particularly Coal to avoid losses by interrupting supplies when power prices fall below its costs to supply.

To replicate the inverse relations between power prices and renewables supply, as empirically validated for Spain and UK in my book, we simulate volumes by "inverting" the binomial tree. That is, volumes' up moves are negative (e.g. declining), while the down moves are positive (e.g. increasing). Power and fuel prices simulations follow the usual up (+) and down (-) moves. Hence, when hydro or geothermal power's volumes are increasing, power prices fall (or vice versa).

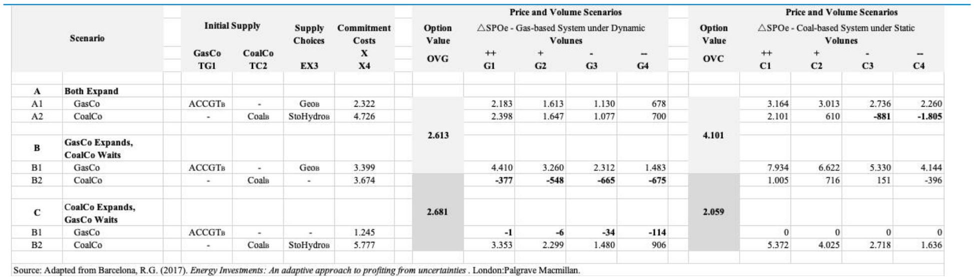
In constructing GasCo or CoalCo's portfolio, the pacing of the growth investments is relevant. This is where our ability to judge the value of moving first or waiting becomes essential to uniquely appropriate the portfolio's returns. We illustrate this by taking CoalCo and GasCo's asymmetric expansion strategy into StoHydro or Geo. The analysis adapts the option games approach to energy investments that Chevalier-Roignant and Trigeorgis (2011) employed.

The option games framework addresses how rival firms' actions produce interacting effects that alter portfolio value under duopoly, hence the firm's strategic positioning as well. The analyses that follow are detailed and adapted from my book, *Energy Investments: An adaptive approach to profiting from uncertainties*.

Asymmetric Expansion: Baseload Hydro and Geothermal

What we see in Table 1 is an abridged version of what I presented in my book. The Option Value for gas (OVG) and coal (OVC) are the results of the binomial tree calculations. It estimates the risk-adjusted (or volatilities-adjusted) payoffs less the capex, under the different price scenarios. In a way, it is a composite value that incorporates how the different levels of volatilities are explicitly considered. The price and volume scenarios show how the values the vary (or delta) from Coal- or ACCGT-only portfolios.

TABLE 1: Strategic Payoffs with Geothermal or Stored Hydro



	Scenario	Initial Supply		Supply Choices	Commitment Costs	Option Value	Price and Volume Scenarios △SPOe - Gas-based System under Dynamic Volunes				Option Value	Price and Volume Scenarios △SPOe - Coal-based System under Static Volunes			
		GasCo TG1	CoalCo TC2	EX3	X X4	OVG	++ G1	+ G2	- G3	-- G4	OVC	++ C1	+ C2	- C3	-- C4
A	**Both Expand**														
A1	GasCo	ACCGT$_B$	-	Geo$_B$	2.322	**2.613**	2.183	1.613	1.130	678	**4.101**	3.164	3.013	2.736	2.260
A2	CoalCo	-	Coal$_B$	StoHydro$_B$	4.726		2.398	1.647	1.077	700		2.101	610	**-881**	**-1.805**
B	**GasCo Expands, CoalCo Waits**														
B1	GasCo	ACCGT$_B$	-	Geo$_B$	3.399		4.410	3.260	2.312	1.483		7.934	6.622	5.330	4.144
B2	CoalCo	-	Coal$_B$	-	3.674	**2.681**	**-377**	**-548**	**-665**	**-675**	**2.059**	1.005	716	151	-396
C	**CoalCo Expands, GasCo Waits**														
B1	GasCo	ACCGT$_B$	-	-	1.245		**-1**	**-6**	**-34**	**-114**		0	0	0	0
B2	CoalCo	-	Coal$_B$	StoHydro$_B$	5.777		3.353	2.299	1.480	906		5.372	4.025	2.718	1.636

Source: Adapted from Barcelona, R.G. (2017). *Energy Investments: An adaptive approach to profiting from uncertainties* . London:Palgrave Macmillan.

We now examine scenarios where CoalCo waits while GasCo substitutes baseload ACCGT$_B$ with Geo$_B$ (or baseload geothermal) to acquire an option on renewables' higher future payoffs under very high (++) or high (+) power prices. This represents a strategic shift where GasCo aimed to reinforce its competitive advantage with ACCGT$_B$.

CoalCo, in contrast, realizes the dire prospects it faces by attempting to "re-institute" with $Coal_B$ its faded glory under coal-based system. Persisting with "expensive" supplies, while "cheaper" gas comes to dominate, $Coal_B$'s days are numbered. To break away from a path of eventual obsolescence, CoalCo could opt to diversify with $StoHydro_B$

When GasCo invests in Geo_B, it is taking a call option on the potentially higher payoffs when power prices are high, given Geo_B's zero fuel costs. In this case, GasCo would proceed to commit when the exercise price X_i (or capital expenditure) is lower than the present value of the expected payoffs S_i, using Year 4 as the starting point when the asset is operationally ready. However, while building the asset, GasCo faces power prices and volumes uncertainties, where the revenue and payoffs potential could vary. During this period, GasCo may choose to abort or continue with their commitment to expand.

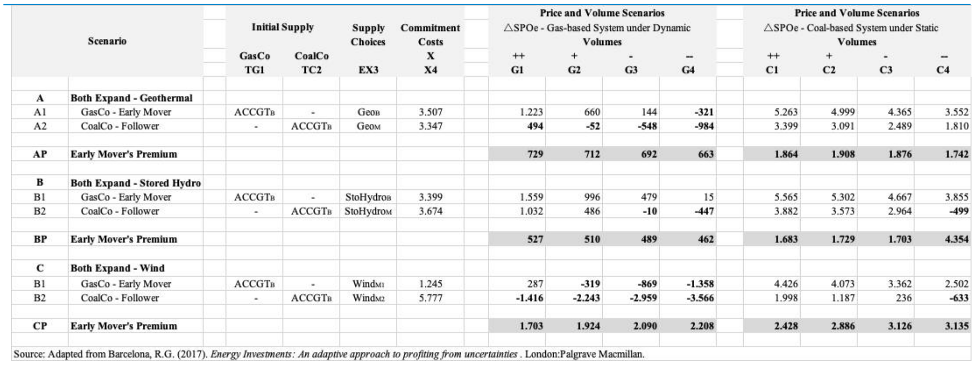
Timing the Commitment: First Mover's Advantage
Renewables' geo-specific resources bestow advantages to firms that could lock in sites with abundant resources (i.e. wind, hydro, or steam). In effect, resource abundance equates to higher utilization rates (or vice versa). In our simulation, we formulate this as a difference in utilization rates where base-load costs are attributed to the early movers in calculating their payoffs. In contrast, late-movers' payoffs resemble that of mid-merit assets. The early movers' premium is the difference between the rival firms' SPO_es.

Let us consider GasCo as an early mover where they opt to commit to Geo_B in Year 1. In turn, CoalCo follows as a late-mover, committing to Geo_M in Year 3. We repeat this analysis using StoHydro and Wind, to ascertain how their combination with $ACCGT_B$ would influence GasCo and CoalCo's portfolio SPO_es.

The results in Table 2 suggest that except when power prices are very high (++), GasCo benefits from locking in abundant renewable resources, while securing stable payoffs from their ACCGT assets. For this reason, GasCo may opt to diversify into higher costs renewables (relative to StoHydro) when power prices are very high (++) or high (+) – if that is the only available resource from where to supply a given market.

CoalCo's position is less straightforward as a follower to GasCo. Under gas-based system, CoalCo's strategic choices are value accretive only under (++) for Geo_M (A1, G1) and (++) and (+) for $StoHydro_M$ (B1, G1-G2). However, as power prices decline, CoalCo's costs disadvantage manifest itself as significant

TABLE 2: Early Mover's Premium – Geocentric Resources



	Scenario	Initial Supply GasCo TG1	 CoalCo TC2	Supply Choices EX3	Commitment Costs X X4	Price and Volume Scenarios △SPOe - Gas-based System under Dynamic Volumes ++ G1	 + G2	 - G3	 -- G4	Price and Volume Scenarios △SPOe - Coal-based System under Static Volumes ++ C1	 + C2	 - C3	 -- C4
A	**Both Expand - Geothermal**												
A1	GasCo - Early Mover	ACCGT$_B$	-	Geo$_B$	3.507	1.223	660	144	**-321**	5.263	4.999	4.365	3.552
A2	CoalCo - Follower	-	ACCGT$_B$	Geo$_M$	3.347	**494**	**-52**	**-548**	**-984**	3.399	3.091	2.489	1.810
AP	**Early Mover's Premium**					**729**	**712**	**692**	**663**	**1.864**	**1.908**	**1.876**	**1.742**
B	**Both Expand - Stored Hydro**												
B1	GasCo - Early Mover	ACCGT$_B$	-	StoHydro$_B$	3.399	1.559	996	479	15	5.565	5.302	4.667	3.855
B2	CoalCo - Follower	-	ACCGT$_B$	StoHydro$_M$	3.674	1.032	486	**-10**	**-447**	3.882	3.573	2.964	**-499**
BP	**Early Mover's Premium**					**527**	**510**	**489**	**462**	**1.683**	**1.729**	**1.703**	**4.354**
C	**Both Expand - Wind**												
B1	GasCo - Early Mover	ACCGT$_B$	-	Wind$_{M1}$	1.245	287	**-319**	**-869**	**-1.358**	4.426	4.073	3.362	2.502
B2	CoalCo - Follower	-	ACCGT$_B$	Wind$_{M2}$	5.777	**-1.416**	**-2.243**	**-2.959**	**-3.566**	1.998	1.187	236	**-633**
CP	**Early Mover's Premium**					**1.703**	**1.924**	**2.090**	**2.208**	**2.428**	**2.886**	**3.126**	**3.135**

Source: Adapted from Barcelona, R.G. (2017). *Energy Investments: An adaptive approach to profiting from uncertainties* . London:Palgrave Macmillan.

losses or erosion of SPO$_e$s. Having calculated the SPO$_e$s for GasCo (the early mover) and CoalCo (the follower), the early mover's premium is simply the difference in SPO$_e$s under each scenario. Hence, for scenario (++) for Geo, we have $729 mln (AP, G1) (i.e. $1,123mln less $494mln) as the excess value (or early mover's premium) appropriated by GasCo.

Being resource-dependent, the access rights to renewables resources could be priced where first-movers are more likely to pay a premium to pre-empt rivals. That is, by paying an access fee (as in a concession) that is below the option value, or an outright purchase that gives such access rights, firms can potentially increase their portfolio value. In this case, the land value or access rights can be priced as a subjective value (i.e. relative to the firm's portfolio endowment). The pre-empting firm secures the whole opportunity (i.e. ensuring that only one firm can expand).

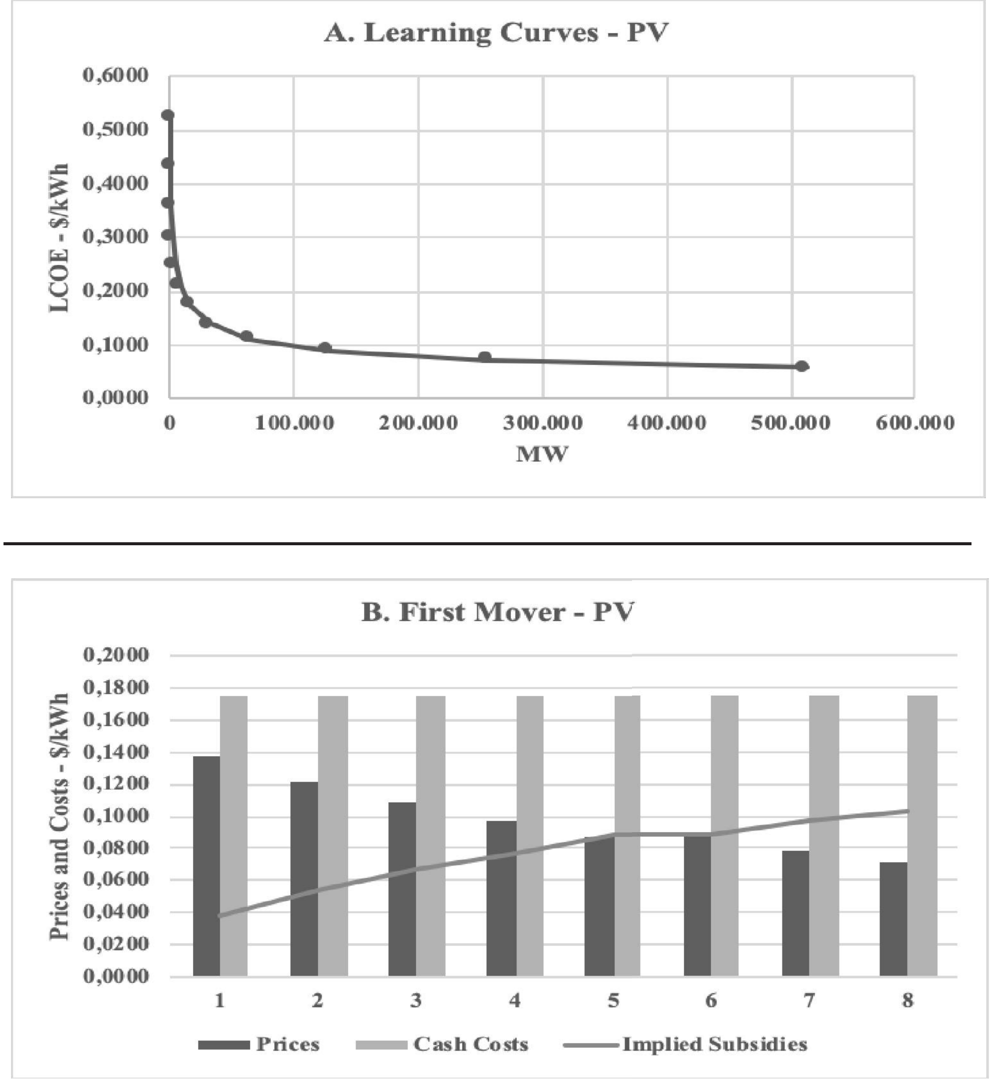
Interestingly, under coal-based system, while the early mover's premiums are significant, particularly for Geo$_B$ and StoHydro$_B$, being late in the game tend to carry a penalty of opportunity loss in terms of foregone portfolio value (A-C, C1-C4). The exceptions are CoalCo's value erosion under very low price-volume scenario (--), where follower CoalCo incurs actual portfolio loss of $499 mln (B2, C4) for StoHydro$_M$, and $633 mln (C2, C4) for Wind$_{M2}$. In contrast, CoalCo's being late in the game under gas-based system does carry actual losses, largely from price erosions.

SOLAR POWER LATE-MOVER'S BENEFITS

Solar and PV enjoy zero fuel costs but suffer from low conversion rate of sunlight to energy. It is not available when it is most needed – at night. Optimistically, conversion for PV is pegged at 22% with degradation setting in within five years, subject to how good the maintenance is. In our example, we focus on utilities scale PV so that the scale is comparable.

The math implies that to produce similar outputs as Coal or ACCGTs, where utilization rates are 85% to 87%, PV would need to install about four times more capacity (1 MW / 0.22 * 0.85 = 3.86 MW). In effect, the comparable capital expenditure at $1,000/kW is $3,860/kW for the equivalent for Coal. Using a 15% conversion rate, which is what actual projects are achieving, the equivalent investment is increased to $5,667/kW. Stored hydro and geothermal are about $2,000/kW to $2,500/kW.

FIGURE 1: Learning Curves and Firm's Cash Returns



Source: Author's calculations

Having established the math, the business media's enthusiasm is curiously premised on "exuberant altruism". The argument follows this logic: Learning curves suggest that future PV costs would fall substantially as schematically shown in Figure 1-A. Policy follow this logic by focusing on volume growth. Generous subsidies kickstart the exuberance. As the addiction to subsidies takes hold, its withdrawal inflicts extreme pains to panel producers, as well as investors. Europe's cuts left the PV industry a trail of bankrupt firms, with China's 2018 cuts possibly repeating this cycle (Hill, 2018).

This brings us to the late-mover's benefits, a reversal of strategy's mantra of a first-movers' win by the *bold* and the *brave*, and the *fastest*.

The first mover (Figure 1-B) is locked-in with "expensive" supplies. As costs fall, the early movers' assets are rendered obsolete by technological advances. This could result in one of two scenarios: a) Subsidies increase over time to close the widening revenue gaps; or in its absence, b) losses spike because of under-recovery when payoffs prove insufficient to recoup capex. Given this prospect, managers may decide to ***wait*** until PV costs have fallen farther.

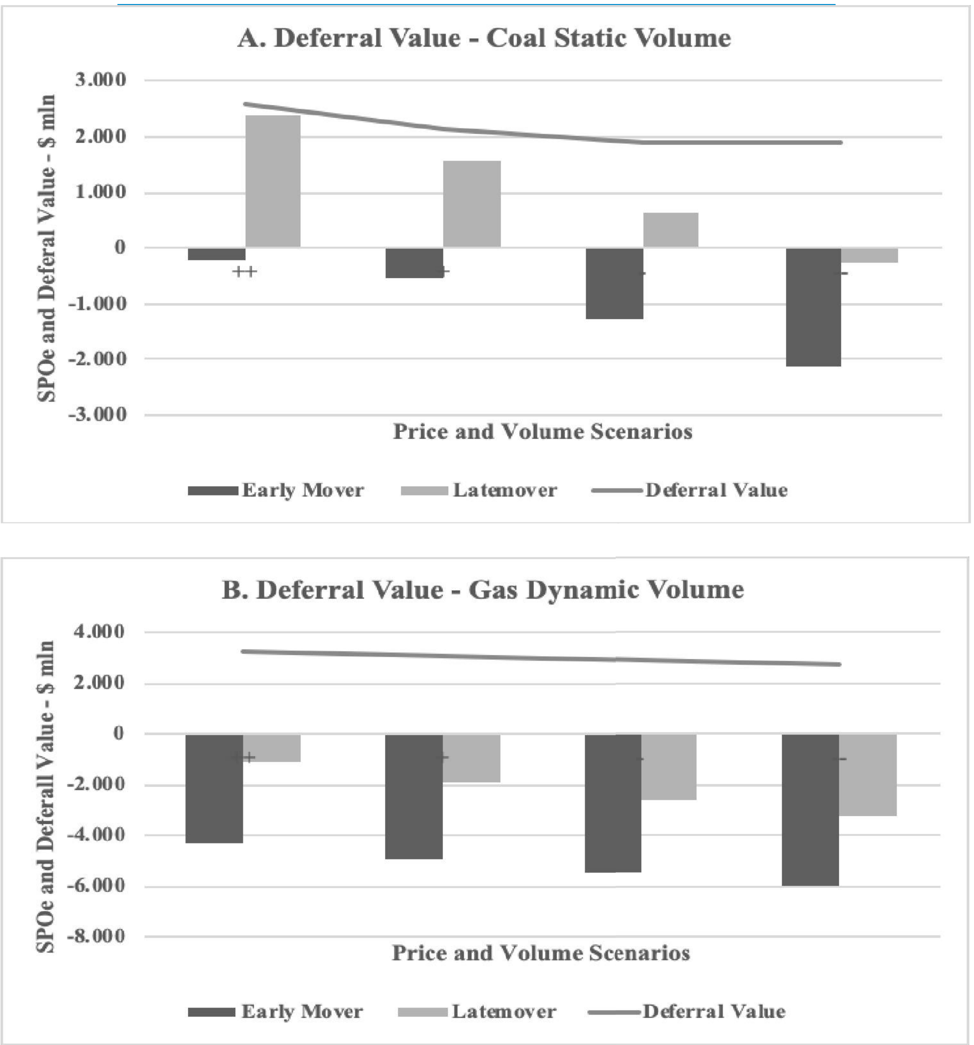
By waiting, investors forego say two or three years of revenues. In a year, there are 8,760 hours (24 h/day x 365 days/year) available to any power generators. For solar, sunlight is available from six to eight hours, with the peak at four hours. This would imply a conversion rate of sunlight to energy ranging from 16% to 33%. The actual rates achieved is around 16%.

For our calculations, we use a 22% conversion rate, where a kW of solar capacity produces 1,927 kWh a year. For every kW of capacity, the revenue loss is about $134 (or $269 for two years, $402 for three years). Deduct the high – low ranges of operating costs from $95 ($0.0495/kWh * 1,927h) to $28 ($0.0146/kWh*1,927h), the annual cash margins are between $39 and $106 (or $78 to $212 for two years, $117 to $318 for three years). In sun-drenched deserts, operating costs may prove higher where water costs more than oil or gas. The scarce resource – water – is essential to clean and maintain the panels so as to achieve the high operational efficiency assumed in the calculations.

PV's installed costs range from $1,500/kW to $1,000/kW, with some suppliers quoting below $1,000/kW. These costs ranges are consistent with the latest rounds of Saudi Arabia / Softbank offers. Roof top solar panels are stuck at $3,000/kW to $3,500/kW. Since 2014, production and installation efficiency accounted for most of the cost reductions, with more slack left for farther efficiency gains. Conversion rates improved only marginally given the silicon's limitations as energy carrier.

This is a far cry from $4,000/kW to $5,000/kW as recent as 2010. Managers looking at these data would do this quick math: To be indifferent, solar costs should fall less than 5.2% to 21.2% in two years, or from 7.8% to 31.8% over three years. With advocates suggesting a more drastic fall, waiting two or three

FIGURE 2: Deferral Value



Source: Author’s calculations.

years could prove more lucrative. On a more realistic note, power prices fell when oil prices declined from $140/bbl in 2008 to less than $40/bbl in 2010 before rebounding to $70/bbl in 2018. To make PV financially viable, it is racing against itself and the energy market: How fast its costs are reduced, and how much oil prices erode (or reinforce) power prices.

While coal is presented as the epitome of what is wrong with today’s energy, energy prices under coal-dominated systems tend to be higher, hence friendlier to PV’s economics (Figure 2-A). Under very high (++), high (+) or low (-) power price scenarios, the late-movers could achieve positive portfolio values by virtue of the higher energy prices. The early mover, in contrast, could only contribute positively when energy prices are very high (++). Consequently, deferring actions could offer the prospect of lower capital outlay and higher positive payoffs.

Gas' dominance shift the energy prices lower, given ACCGT's lower supply costs. This implies a squeeze on Coal and PV's revenues (Figure 2-B). PV's financial prospects drastically deteriorate under all price scenarios considered. PV could only survive financially with large injections of subsidies or the willingness of *altruistic consumers* to pay above market prices for their energy. In this case, managers would rather wait for longer. Under highly subsidized regimes, its longevity would depend on how long payments are sustained under increasingly hostile political contexts. As consumers realize that PV investors take little financial risk, while kept afloat at their expense, consumers would coax regulators to cut subsidies.

CONCLUSION AND STRATEGIC IMPLICATIONS

Managers need to explicitly evaluate how volatilities, rivalries, and dynamic interactions of a portfolio of technologies, could impact their firm's strategic value and position. By taking these factors into account, managers could value strategic and operational flexibility, while identifying under-exploited opportunities that NPVs ignore.

Renewables alter the competitive dynamics when its inclusion erode power prices when volume growth is stable (e,g. Europe and USA). As a result, the firm that expands to meet a given extra demand using traditional fossil fuel technologies (Coal or ACCGT) face potential payoffs erosion, should rival firms expand using renewables.

Geocentric renewables are dependent on resource availability that is not readily transportable. Given their varying costs and reliability, preferred sites with abundant resources are relevant for differentiating portfolio performance. For this reason, the value of pre-empting competitors may outweigh the benefits that latecomers may derive from falling capacity costs in the future.

Solar and PV's rapidly declining asset costs portend an era where solar power may come of age. However, far from propelling rapid adoption, "learning effects" produce a paradox. As asset cost is expected to decline with certainty, managers may withhold commitments to benefit from lower future investments.

Two insights are gained that lead to different technology choices (relative to what NPV would prescribe):

1. *Market context for decision*: Asymmetric costs could erode the firms' value when cheaper gas replaces coal to set marginal prices. Deeper

renewables penetration adds to this price pressure, when “expensive” supplies are displaced.

2. *Initial asset endowments matter*: Renewables’ value differs for Coal- or ACCGT-endowed portfolios, as prior technology choices influence prospective financial payoffs.

The strategic implications that emerge can be thought provoking:

Coal-dominant systems tend to produce higher power prices. Ironically, while Coal is targeted for closure to give way to renewables, it does offer a more benign pricing ecosystem than gas that favors renewables adoption.

Counter-intuitively, “act fast” may impair the firms’ viability, as in Solar or PV investments. Under these circumstances, by “moving slow” or “being late”, managers’ prudence may prove virtuous and value accretive.

In the end, by understanding the nature of uncertainties, and learning to evaluate its value impact, managers may incorporate these insights into their strategic moves. By recognizing dynamic markets for what it is, rather than imagine a world guided by (non-existent) policy foresight, renewables’ portfolio hedge value may be recognized, and encourage greater commitments.

Future research could benefit from examining how organizations, and its capabilities, could embed a more adaptive approach to profiting from uncertainties. In so doing, the factors that accelerate (or impede) a low carbon transition may be revealed within how managerial decisions and policy actions interact.

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