Molecules and Electrons:
Rent, Learning, and the Petrostate's Dilemma

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Abstract

A hypothesis circulating in Bucharest holds that Romania's turn toward gas serves an American strategy to keep Europe on fossil fuels and out of an electrified, autonomous future, and it prices the stake as a 1.7 to 3.6 percent hit to the United States current-account deficit. The intuition is right and the arithmetic is wrong, and fixing the arithmetic requires distinguishing two forms of energy power that the word energy fuses. Molecule power is power over a flow metered at a chokepoint: the customer must keep buying, the rent recurs, the leverage is a tap. Electron power is power over a stock and a standard: the customer buys the capital once, the fuel is then free, and the residual dependence is on equipment, software, and standards rather than on a daily delivery. The asymmetry that organizes everything is that molecule revenue requires the customer to stay un-electrified, so a fossil exporter has a structural interest in delay. This paper builds the smallest dynamical model that makes the interest legible: an importing region's electric share follows a replicator equation with technological learning, which is bistable, with an interior takeoff threshold the exporter's price can move. Three results follow. The exporter faces a dilemma between harvesting the fossil age at a high price, which accelerates the importer past the threshold and ends the rent, and extending it by limit-pricing, which keeps the importer trapped; extending beats harvesting by a present-value factor near 1.9 only when the exporter is patient and substitution would otherwise be fast, so a state that suppresses its own price reveals it believes takeoff is near. The original current-account arithmetic is an order of magnitude too large and in the wrong ledger: the displacement is about 0.13 to 0.23 percent of the deficit, while the stake the exporter actually defends is the capitalized European rent a takeoff terminates, near 289 billion dollars, roughly 113 times the annual trade-flow figure. And the delay is bounded, because the learning curve is global: an exporter that suppresses one region's deployment still faces a threshold dragged down by whatever rival keeps deploying, so limit-pricing buys a finite delay of years, not a reprieve. The Romanian outcome the hypothesis fears is generated by each actor's independent optimum without coordination, which makes the conspiracy reading not merely unproven but unnecessary, and pricing the incentive is not establishing the instruction.

1. A Hypothesis from Bucharest

A reading of Romanian politics has been circulating that deserves a better instrument than it has been given. It runs like this. The country's growth model is in crisis, and its political class, across the presidency and the nationalist opposition alike, has thrown itself at gas, understood narrowly as the molecule, as the way out. This turn is not only domestic. It is convenient for a United States that has declared energy dominance a strategic objective and wants Europe anchored as a buyer of American liquefied natural gas for decades, because a Europe that electrified and built its own electron economy would be a Europe that stopped buying. On this reading the sidelining of a sovereign European electricity project is a transatlantic business interest wearing the costume of energy security, and Romania's leaders are playing, wittingly or not, for the American side.

The hypothesis then tries to price itself, and this is where it stumbles. It estimates that a European shift toward electricity would displace some American gas, costs that displacement at 15 to 25 billion dollars a year, and reads the result as a 1.7 to 3.6 percent deterioration of the United States current-account deficit, large enough to motivate a strategy. Every number in that chain is off. The displaced volume is real but the revenue attached to it is inflated by close to an order of magnitude, the current-account deficit it is measured against was nearer 1.12 trillion than the 700 to 900 billion assumed, and the resulting share is a tenth of the figure claimed. The honest correction looks like a refutation.

It is not a refutation. The intuition that a large stake is in play is correct, and the arithmetic fails because it is the wrong arithmetic, applied to the wrong account. To see why takes a distinction the word energy hides, between two forms of power that behave so differently that a strategy rational in one looks irrational when scored in the other. This paper draws the distinction, builds the smallest model in which it has teeth, and uses the model to relocate the stake the Bucharest hypothesis was reaching for. The question is not whether Romanian actors take instructions from Washington, which the public evidence does not show and the argument does not need. It is what kind of object the stake is, and why a fossil exporter would defend it even at the cost of suppressing its own price.

2. Two Forms of Power

The contrast between a petrostate and an electrostate has been drawn most sharply by Adam Tooze, who treats the two as ideal types of how a state converts energy into geopolitical power (Tooze, 2025). The distinction is older than the names. Albert Hirschman showed in 1945 that the power one country holds over another through trade is the power to interrupt a flow the other has come to depend on, and that the leverage is largest where the dependence is hardest to redirect (Hirschman, 1945). Molecule power is Hirschman's power in its purest contemporary form. Oil and gas are flows, metered at wells, straits, pipelines, and regasification terminals, and the exporter's leverage is the standing option to slow or stop the flow at a chokepoint the importer cannot quickly bypass. The rent recurs because the molecule is consumed: every unit burned must be bought again. The geopolitics of the hydrocarbon age is a geopolitics of taps (Yergin, 2011; Goldthau and Sitter, 2015).

Electron power is built on a different object and obeys a different logic, which the emerging literature on the geopolitics of renewables has begun to map (Scholten and Bosman, 2016; Scholten, 2018; Overland, Bazilian, Ilimbek Uulu, Vakulchuk and Westphal, 2019). Electricity from sun and wind is not a flow an exporter controls; the sunlight reaching an installed panel cannot be embargoed. What is tradeable, and therefore what carries power, is the capital stock and the standard: the turbines, modules, batteries, inverters, grid equipment, and the software and technical norms that bind them. The dependence this creates is not the recurring dependence of a fuel bill but the one-time dependence of a capital purchase, followed by a long tail of spares, replacements, financing, and standards lock-in. An electrostate's leverage is not a tap it can close but a platform others build on, and its rent is not the price of a molecule consumed but the margin on equipment installed and the control of the next generation's standard.

The asymmetry that organizes the rest of this paper falls directly out of the contrast. A molecule exporter is paid only while the customer stays on molecules. Every kilowatt-hour an importer generates from its own installed stock is a unit of fuel it does not buy, so electrification does not merely lose the exporter a sale, it retires a customer. The fossil exporter therefore has a structural interest that the electron exporter does not: an interest in delay. Delay is the whole game. This is the interest the Bucharest hypothesis was pointing at, and it is real, but it has to be priced in the right account, which is not the annual trade balance.

Three qualifications keep the distinction honest, and the model below respects all three. The United States is not a petrostate in the fiscal sense; it holds molecule power and electron power at once, and the precise object of analysis is its fossil-export-dominance strategy, not the country (Tooze, 2025). An importer that electrifies on another power's equipment, as Europe would on Chinese modules and batteries, exchanges a fuel dependency for an industrial one and does not thereby become sovereign, which is why the European Union's Net-Zero Industry Act tries to onshore the stack rather than merely deploy it. And electricity is not yet a large share of final energy anywhere: the International Energy Agency puts it near 0.28 in China, 0.22 in the United States, and 0.21 in the European Union, so the transition the model describes is early, which is the regime in which a strategy of delay has the most to gain (International Energy Agency, 2025).

3. The Transition as a Bistable System

Let $x(t) \in [0, 1]$ be the share of an importing region's useful energy services supplied electrically, so $1 - x$ is the molecular system. Substitution between the two is a competition between systems, and the natural minimal description is a replicator equation, the workhorse of evolutionary and adoption dynamics (Hofbauer and Sigmund, 1998):

$$\dot{x} = \eta\, x(1 - x)\, \Delta(x),$$

where η is the speed of capital replacement and adoption and Δ is the generalized advantage of the electric system over the molecular one, in cost, security, and political support. The advantage is not constant in x, because deployment changes it. Cumulative installation drives equipment costs down a learning curve, the empirical regularity that each doubling of installed capacity lowers unit cost by a roughly fixed fraction, which holds across clean-energy technologies more reliably than for fossil extraction (Nagy, Farmer, Bui and Trancik, 2013; Way, Ives, Mealy and Farmer, 2022). Integration costs push the other way, since grids and storage get harder to balance as the variable share rises. Folding a local linearization of both into the advantage gives $\Delta(x) = A + (\ell - \kappa)x$, with ℓ the learning slope and κ the integration slope, so that

$$\dot{x} = \eta\, x(1 - x)\, [A + (\ell - \kappa)x].$$

This cubic has three equilibria, $x = 0$, $x = 1$, and an interior point $x^\dagger = -A/(\ell - \kappa)$. When $A < 0 < A + (\ell - \kappa)$, both $x = 0$ and $x = 1$ are stable and $x^\dagger$ is the unstable threshold between them. The system is bistable, and that bistability is carbon lock-in stated as a dynamics: below $x^\dagger$ the economy slides back to a fossil equilibrium, above it learning and coalition feedback carry it to full electrification, and a subsidy that pushes it across does not have to be maintained once it is over (Unruh, 2000; Arthur, 1989; David, 1985). Lock-in is a basin of attraction, not a conspiracy. The same directed-technical-change feedback that makes the threshold also makes it sticky: policy that redirects innovation toward the clean sector changes relative costs endogenously, so the advantage a region has tomorrow depends on what it deploys today (Acemoglu, Aghion, Bursztyn and Hemous, 2012).

The threshold is the exporter's point of leverage, because the exporter's price enters A. A higher fossil price raises the advantage of electrifying, $A(p_P) = A_{\text{base}} + \alpha(p_P - p_{\text{ref}})$, so the exporter's pricing decision is also a decision about where the importer's threshold sits. In the calibration used here, anchored to a reference price near the 2025 average, the advantage turns positive and takeoff becomes automatic above a price of about 9.00 dollars per thousand cubic feet, the importer's current share sits exactly on the threshold at a price near 7.88, and below a price near 3.67 the electric equilibrium becomes unreachable altogether. Between the lockout price and the trap price lies a window in which the exporter, by holding its price down, can keep the importer's threshold above the importer's current position and so keep it trapped on the molecular side. The price is a lever on someone else's transition.

Figure 1: The exporter's price sets the importer's takeoff threshold $x^\dagger$. Above the trap price (near 7.88) the threshold falls below the importer's current electric share $x_0 = 0.21$, so the importer is already past the barrier and electrifies; below it the threshold rises above x_0 and the importer is trapped on the molecular side; below the lockout price (near 3.67) the electric equilibrium is unreachable. The shaded band is the unit interval. The window between lockout and trap is the exporter's room to suppress its own price and keep the importer fossil.

4. Harvest or Extend

The lever has a cost, and the cost is the heart of the matter. The exporter earns its rent on the molecules it still sells, a margin times a volume, and the volume is $1 - x$. Raising the price raises the margin but, by lifting the importer over its threshold, sets x climbing toward 1 and the volume toward zero. Lowering the price into the trap window protects the volume but thins the margin. Both cannot be had. The exporter is choosing not a price but a path, between two strategies that can be named harvesting and extending the fossil age.

The two are priced by integrating the discounted rent stream along the transition each price induces. Harvesting sets a high price, above the trap, and collects a fat margin while the importer takes off and the stream runs out. Extending sets a low price, inside the trap window, and collects a thin margin on a volume that persists because the importer never crosses. For an exporter that is patient and faces fast substitution, the persistent thin stream is worth more than the fat brief one. At a discount rate of 0.03 and a substitution speed at which an unobstructed importer would electrify within roughly a decade, the present value of extending reaches about 259 billion dollars against 135 billion for harvesting, a ratio near 1.9 in favor of suppressing the price.

That ratio is not a constant of nature, and its dependence is the sharp result. Extending wins only in a corner of the strategy space. Holding substitution fast, it beats harvesting only for discount rates below about 0.165; a sufficiently impatient exporter always harvests, because the future volume it would protect is discounted into irrelevance. Holding patience fixed, extending beats harvesting only when the substitution speed exceeds about 0.20; against a slow transition there is nothing to defend against, and the exporter may as well take the high margin now. Limit-pricing is rational precisely when the importer is poised to move, a fast transition met by a patient incumbent. The implication runs backward, from strategy to belief. A fossil exporter that holds its price down, forgoing current rents, is not behaving irrationally and is not merely greedy for market share. It is revealing that it expects the unobstructed transition to be fast, because only that expectation makes the sacrifice pay. The strategy is a tell. Energy dominance pursued through cheap, abundant export is a posture whose own existence is evidence that its strategists believe the electron transition is close.

5. The Stake Is Not the Trade Balance

With the dilemma in hand the Bucharest arithmetic can be repaired rather than merely corrected. Take the displacement the hypothesis itself proposed, 5 to 9 billion cubic meters of American gas pushed out of Europe by a marginal electrification step. Valued at the 2025 export price, that is roughly 1.4 to 2.6 billion dollars of lost sales, which against a 1.12 trillion dollar current-account deficit is a share of 0.13 to 0.23 percent. The original estimate of 1.7 to 3.6 percent was too large by an order of magnitude, and the correction stands. A defender of the deflationary reading would stop here and conclude the stake is trivial.

The stake is not trivial; it is in a different account. The current-account figure prices one year of one marginal displacement. What the exporter defends when it works to keep an importer below

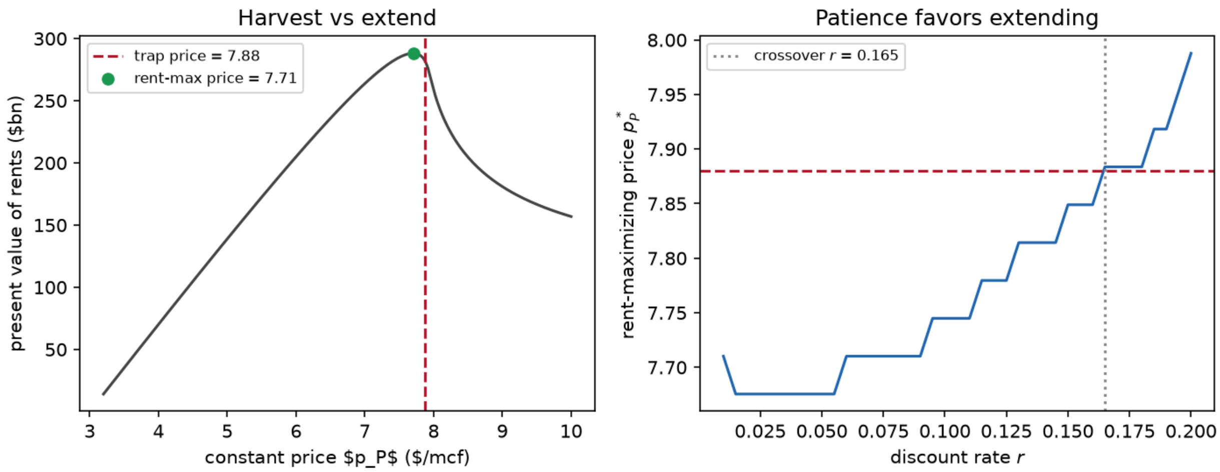

Figure 2: Left: present value of the exporter's rents as a function of a constant export price, under a patient exporter facing fast substitution. The value peaks inside the trap window, below the trap price (dashed): limit-pricing, not harvesting, maximizes the discounted rent. Right: the rent-maximizing price as the discount rate rises. Below the crossover near $r = 0.165$ the optimum is to extend (price below the trap line); above it the optimum flips to harvest. Patience favors suppressing the price.

its threshold is not one year's sales but the entire European rent stream that crossing the threshold would terminate, capitalized. The annual rent on the exporter's current European volume runs to roughly 15 billion dollars, and capitalized over the roughly 60-year working life of the molecular capital, the present value at stake is near 289 billion dollars, not far below the 304 billion of an undated perpetuity. That is about 113 times the annual current-account number the hypothesis tried to use. The three-figure precision is spurious, and the order of magnitude is the whole of the claim: the exact stake moves with the assumed margin, the discount rate, and the horizon, none of them measured here, but no defensible setting of them brings a capitalized rent stream within an order of magnitude of a single year's coupon. The mistake in the original argument was not that it overestimated the stake but that it underestimated it, by pricing a perpetuity as a single coupon and then booking the coupon to the wrong ledger. Molecule power is a claim on a recurring flow, and the value of a recurring flow is a capital sum, not a year's receipts. A flow is a perpetuity. The trade balance is where the molecule shows up; the rent account is where it lives.

6. Romania at the Knife-Edge

Romania is the case that motivated the question, and the model places it precisely at the edge it fears. A country near its own threshold can be tipped either way by where it directs the next decade of capital, and Romania's choices are loading the molecular side. The Neptun Deep development is expected to produce around 8 billion cubic meters a year from 2027, roughly doubling national output, and the gas-fired generation and pipeline commitments around it raise the standing political weight of the fossil coalition and lower the advantage term A. In the model's language, this raises Romania's own takeoff threshold above its current position and pushes it toward the fossil

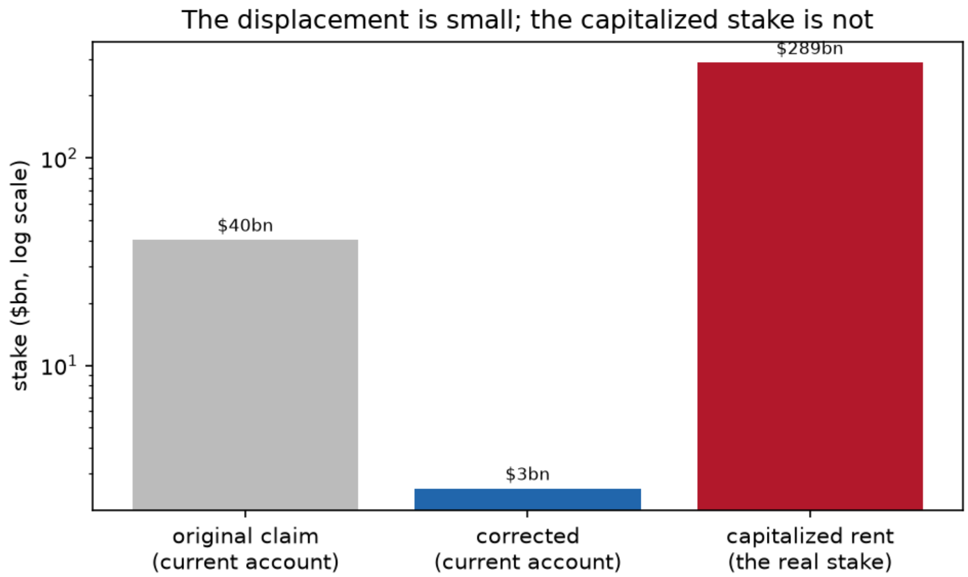

Figure 3: The marginal displacement is small as a share of the trade balance, and the original estimate (gray) overstated even that. But the stake the exporter defends is the capitalized European rent a takeoff would end (red), near 289 billion dollars, far above the annual trade-flow figure. The vertical axis is logarithmic. The deflation of the current-account claim and the inflation of the true stake are the same correction seen twice.

equilibrium, which is the lock-in the Bucharest hypothesis names.

The hypothesis errs only in the last step, from outcome to agent. The lock-in is real and the complementarity with American interests is real, but the model produces both without any coordination. Each actor is optimizing its own objective: a domestic rent coalition of producers, ministries, and contractors that captures gas revenue directly; a security logic that reads domestic gas as insurance against Russian supply and a lever over the region; a growth-model crisis that makes a fast, fiscally legible export the most attractive thing in reach; and an American export strategy with its own reasons to want Europe on molecules. These optima point the same way without being aligned by anyone, and the joint outcome, a Romania that deepens its molecular commitment while Europe's electron project waits, is overdetermined. When an outcome is produced independently by four mechanisms, the hypothesis that a fifth, a coordinating instruction from Washington, is also required is not refuted so much as made unnecessary.

The case carries one further complication that cuts against the subordination reading directly. Romanian Black Sea gas competes with American liquefied natural gas. The 8 billion cubic meters of Neptun Deep sit squarely in the range of the 5 to 9 billion the hypothesis imagined Europe displacing, and a molecule sold by Romgaz or its partners is a molecule not bought from a Gulf Coast terminal. Romania and the United States are aligned at the level of the energy regime, both served by Europe staying on gas, and rivals at the level of the supplier, each wanting its own molecule in the pipe. The relationship is structural complementarity with commercial rivalry, not subordination, and the distinction matters for what evidence would settle it. The public record establishes congruence, that Romanian and American positions point the same way. It does not establish the temporal sequence in which one preceded and produced the other, and it does not establish the instruction. Pricing the incentive, which is what this paper does, is a different act from documenting the order, and the model is built to keep them separate.

7. The Delay Is Bounded

There is a last asymmetry, and it is the one that limits how much the exporter's dilemma is worth solving in its favor. The learning curve that lowers the cost of electric equipment is driven by cumulative deployment, and cumulative deployment is global. An exporter that succeeds in suppressing one region's deployment, holding that region's advantage term down by limit-pricing, does nothing to the modules and batteries a rival electrostate keeps installing elsewhere. Those installations keep dragging the global cost down, which means the advantage term floats upward over time wherever the importer sits, independent of the exporter's price. The threshold the exporter is defending is being lowered by a hand the exporter cannot reach.

The consequence is that limit-pricing buys time, not a reprieve, and the amount of time is set by the rival's deployment rate rather than by the exporter. If a constant limit-pricing strategy holds an importer's advantage a fixed distance below its takeoff point, the global learning lift erases that distance after a delay inversely proportional to how fast the rival deploys. In the model's units a slow rival deployment buys about 24 years, a rate four times faster buys about 3, and every positive rate buys a finite number. The exporter cannot drive the rival's learning rate to zero, because the rival deploys for its own reasons in its own market, so the delay has a floor it cannot lower past. The clock keeps running. This is the structural fact under the surface politics: the molecule's last power over the electron is the power to set the clock, not to stop it. Energy dominance, pursued through the patient suppression of price, is a delaying action against a threshold that someone else is steadily pulling down, and it can be read most precisely not as a plan to prevent the electron age but as a bet on how many years of molecular rent remain before it arrives anyway.

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