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Carnot Local, Brownian Global

Everything you need to know about proof-of-work mining economics and dynamics

CONTENTS

FOREWORD

Before You Start

What this book assumes, what it leaves out, and who it is for

This book explains one machine. Not a network, not an investment, not a movement. A machine, in the ordinary sense of a thing with parts that push against each other and produce an output. Proof-of-work mining is that machine, and most writing about it describes the weather around it rather than the mechanism underneath.

It assumes almost nothing. If you know that mining involves computers using electricity to earn coins, you know enough to start. Everything past that gets built here, in order, and any term that carries weight is defined the first time it appears. Nothing is left to be inferred from context or looked up elsewhere.

The Shape of It

Part One tells the story with no numbers at all. Two full turns of the cycle, one phase to a chapter, from the moment a price first exists to the second time the market falls still. Reading it should leave you able to recognise which part of the cycle you are looking at and say why it is there.

Part Two puts units on the same story. What a machine spends, what a coin costs, why buying hardware and running it are the same expense on two schedules, and why waiting is a third cost that never stops being charged.

Part Three adds the piece the first two leave out. Fees. A second way miners get paid, small today and eventually the only one, with the honest caveat that this part reasons forward rather than reporting back.

The closing chapters test the book's own title against everything built before them, trace both halves back to the thought experiments they came from, and say plainly what is still unsettled.

What Is Deliberately Missing

No network is named anywhere in these pages. No machine model, no dates, no prices. That is not coyness. The mechanism is identical wherever it runs, and naming examples would date the book and invite arguments about particular projects that have nothing to do with whether the machinery works as described.

For the same reason the book takes the sound case and follows it carefully. It makes no attempt to catalogue the ways a network can leak value, which is a large subject with a shape of its own. Where that matters, the text says so and points you somewhere it is handled properly.

> *A mechanism is easiest to see where it runs cleanly. Everything here describes a machine with its parts intact.*

Its Companion

This sits beside a longer collection called The Instrument, which works the same territory from the monetary side rather than the mining side. The two overlap at the edges and neither depends on the other. If you want the taxonomy of what makes one network sounder than another, or the fuller treatment of what a coin measures, that is where it lives.

Start here if you want to know how the machine runs. Start there if you want to know what it is measuring.

PART ONE

The Story

One phase of the cycle per chapter, twice around, told with no numbers so the shape is clear before the arithmetic arrives

CHAPTER ONE

Hot Machines, No Price

Before there was a market, there was only heat. Then, one day, the heat met a price, and something began that had never existed before

HOT COINS, HOT ASICS · THE CYCLE BEGINS

Every fair-launched proof-of-work network begins the same way. Nothing pre-allocated, nothing promised in advance, just software released into the wild. Start anywhere later and the rest of this book will not make sense.

At the start, a machine runs and nothing is pricing it. An ordinary computer, doing ordinary work, solving a puzzle that yields a coin nobody outside a small circle has tried to buy. No market. No number to check the effort against. Whoever runs that machine runs it on belief, and the belief has a definite shape: this thing is a tradable commodity, and a tradable commodity can eventually be exchanged for goods, services, or another currency. Nothing available yet can confirm or refute it.

From CPU to ASIC, Before Anyone Was Watching

The hardware tells the story by itself. Mining began on ordinary processors, the same chips already sitting in everybody's desktop, handling this work as one task among many. As word spread, graphics cards took over. Built for rendering images, they turned out to suit the repetitive number-crunching mining demands.

Then came a stranger intermediate step: field-programmable chips, hardware reconfigured for the task rather than built for it. After that, the

final form. Application-specific integrated circuits, silicon designed for one purpose and incapable of any other.

Those steps are not the same kind of step, and the difference explains the pacing. Moving from a processor to a graphics card costs nothing but software. The hardware was already bought, sitting in the machine, doing something else. Anyone could switch over on an afternoon and switch back just as easily. Field-programmable chips and purpose-built silicon are a different proposition entirely: money committed upfront against a return nobody has promised, on hardware that will never do anything else if the bet is wrong.

So the progression waited. Nobody commits capital to a machine that can only mine until mining visibly pays, and nobody could see whether it paid until there was a price to check against. The early steps happened because they were free. The expensive ones happened later, for the reason expensive things always happen.

Each step pushed the same trade further. Surrender flexibility, gain efficiency. No market rewarded this. It happened because the people running these machines expected the coin to justify the effort someday, and kept spending on that expectation alone.

> *The machines were hot long before anyone outside a small circle knew they existed. Heat came first. Price had not been invented yet.*

The Circuit Closes

At some specific moment, that changes. Someone offers to buy the coin. Someone else agrees to sell it. A price exists where none did before.

Everything that follows starts here, because two things that had sat apart finally touch. On one side, physical mining effort, already running, already burning money, indifferent to whether anyone outside noticed. On the other, a price arriving from strangers who have no idea what the mining costs, valuing the coin purely on what they guess its scarcity is worth.

Two separate things touching for the first time take the shape of a physical event: fusion. A star is not a star until enough mass, under enough pressure, crosses a threshold and two separate conditions collapse into one self-sustaining process. Cost and price behave alike. The instant they connect, the connection stops sitting still. It begins pulling on itself.

Coming In Hot

That first price arrives hot rather than gently. A market discovering a scarce thing, with no information about what producing it costs, overshoots. Price lands above the physical cost of production, not below it and not level with it.

That distance has a name this book returns to constantly. The profitability gap is price minus cost: what a market will pay, less what a machine spends earning the payment. Here, at the beginning, it opens for the first time and opens wide.

What the Gap Does First

A wide profitability gap does not sit quietly. It moves people.

The most direct way to act on it is also the most literal: sell coins already sitting in a wallet, buy machines, mine more. That move recurs constantly from here on. Coins shift out of reserve and into circulation, and abundance begins. Not a crisis, just what people do once they notice the coin in hand is worth more than the cost of producing another.

This moment has a name: hot coins, hot ASICs. The shorthand needs explaining once. Coins and ASICs get tracked separately, each either hot or cold. Hot means rising, in demand, wanted. Cold means the reverse. They do not always move together, which is the point of tracking them apart. Here, both run hot at once. Price has just met a cost that already existed, and the machines generating that cost were already spinning, waiting.

What Comes Next

So it starts with heat and no price. Then price arrives from outside, running hot, and the connection between them starts pulling in capital, machines, and coins together.

This particular moment happens once. Every cycle afterward starts from somewhere else, because the machines involved are no longer meeting a price for the first time. They are answering one that already exists. What follows repeats in shape, but never repeats this.

None of it can accelerate forever. The next chapter follows what happens when everyone who spots the same obvious opportunity acts on it at once.

CHAPTER TWO

Everyone Saw the Same Opportunity

A gap that obvious keeps no secrets, and closes fast once everyone spots it together

COLD COINS, HOT ASICS · THE FIRST TURN

The last chapter ended with a wide gap between price and cost, and coins flowing out of reserve into circulation as holders spent that gap on the machines that would close it. Such a discovery stays private for about as long as it takes somebody else to reach the same conclusion.

Once profit becomes visible, more than one manufacturer notices, and more than one decides to build into it.

Everyone Builds the Same Thing

Nobody can keep a wide, visible profit gap to themselves, and the pattern repeats throughout this book. Every manufacturer capable of building competitive hardware sees the same number the first one saw, and faces the same incentive.

So they build, at roughly the same time. Several manufacturers, several designs, all racing hardware to market while the gap stays wide enough to justify the effort. None of them collude. None of them need to. They read the same signal and reach the same conclusion separately. Call it forced convergence: independent actors, uncoordinated, landing on the same number because one shared cost binds every one of them.

Then You Want to Go Home

A miner recognizes this moment by feel. The machines land all at once, from every direction. Hashrate does not creep. It spikes, as units from every competing manufacturer come online inside the same few weeks.

The party ends here, and the order of events matters. Price moved first. Coins were sold faster than demand could absorb them, price stalled and turned, and only then did the hardware ordered against the old, wider gap finish production and reach the floor. Months separate the two. A miner watching price fall while hashrate keeps climbing is not seeing a contradiction, only the lag between deciding to build a machine and running it. Difficulty adjusts to match hashrate. As hashrate spikes, difficulty climbs to meet it, and a machine that earned a comfortable margin weeks ago now splits the same reward against far more competition. Profit does not taper. It collapses, because the hashrate behind it landed in a lump rather than a trickle.

> *Nobody closes the gap on purpose. It closes because everyone who could see it moved at once.*

Capex Starts to Fall

Manufacturers who built for the wide-margin moment now face a market where the margin has already collapsed. New-unit prices start falling, because unsold inventory in a shrinking market becomes a liability by the week.

Meanwhile a second supply appears. Miners who bought at the top, staring at collapsed profit, sell their machines rather than run them at a loss. Barely any used hardware existed a chapter ago. Now it floods in, because everyone who bought near the peak faces identical sums on the same schedule.

The Used Market Wins

The used market works like a heat sink. It does not stop heat from being generated. It gives the excess somewhere to go, soaking up the machines, the capital, and the urgency a bull phase throws off, so everything else can cool toward something stable instead of cooking indefinitely.

Here is the mechanical turn this chapter exists to describe. A manufacturer selling new must cover production cost. A miner selling used need not. They are salvaging whatever value remains in a machine that has stopped earning its keep, and will take a steep discount to be rid of it.

So the used market undercuts new pricing, and once it does, it wins the sale outright. Given a new machine at the manufacturer's floor and a near-identical used one below it, few buyers pay the premium. New sales slow. Used sales accelerate. The manufacturer who set this chapter in motion by building into an open gap now watches the wreckage of that same cycle outcompete the product.

Nineteenth-century railroads fit this better than a gold rush does. A gold rush ends with the gold gone and the shovels worthless, dead capital with nothing left to do. That is not what happens here. Railroads tell the truer version. Fortunes went into laying track during a genuine mania, most of the builders went bankrupt, and the track stayed, carrying trains long after the money that funded it had vanished. These machines do likewise. The capital gets wiped out. What survives is not scrap but infrastructure, the substrate everything later in this book runs on, still producing blocks regardless of who lost their shirt building it.

The Party Ends

A chapter that opened with everyone rushing the same opportunity closes with the rush dismantling itself. Hashrate spiked, profit crashed, and the used market took the lead from the manufacturers who built the machines to begin with.

It does not stop here. Whatever just crushed mining profit is about to reach the coin, for the identical reason. Too many people saw the same thing and moved together.

CHAPTER THREE (A)

Everything Stops Moving at Once

Machines stop changing hands. Coins stop changing hands. The bottom is not a crash but a total stillness

COLD COINS, COLD ASICS · THE FIRST BOTTOM

The last chapter ended with the used market winning, undercutting the manufacturers who built into the mania. That victory expires too, and watching it expire is how this chapter finds the bottom.

The Used Market Runs Out of Reasons to Move

A used market that keeps winning eventually exhausts what let it win. Machines dumped once by capitulating owners do not get dumped twice. New units, pinned at the manufacturer's floor, stopped attracting buyers a while back and largely stopped arriving. The hardware side settles into a standstill. Survivors keep running, keep mining, and stop changing hands. Nobody selling has inventory left. Nobody buying has cause to bid above the price already sitting there.

Hardware prices settle at whatever the marginal cost of production has become. Nobody declared that figure. No other figure remains available.

Why the Fall Is Loud Before It Goes Quiet

Stillness at the bottom does not arrive gently. It is the exhausted endpoint of something loud, and the loud part explains why the quiet holds once it comes.

Early in a fall, with volume still moving and buyers still willing to take the other side lower, a prisoner's dilemma runs. Nobody wants to be the last holder in a position that keeps getting cheaper. Selling now at a loss beats selling later at a bigger one, and everyone reasoning that way simultaneously is precisely what drives price down. Each buyer steps in below the last, not from misjudgment, but because that is the coin's worth to somebody willing to catch a falling knife.

It continues exactly as long as volume permits. While willing sellers and willing buyers keep meeting at lower and lower prices, the fall keeps moving. It halts when that volume dries up, when nobody remains willing to sell into further weakness and nobody remains willing to catch it. Not a change of heart. A market that has run out of players.

The Coin Goes Quiet the Same Way

The coin follows the same pattern for a related but separate reason. Coins do not vanish when price falls, and somebody owns every one of them at every moment. What changes is willingness to move.

A trader and a miner both chase a gap, but one chases a soft cost, whatever the coin was bought for, and the other a hard one, the physical expense of running a machine, fixed by physics regardless of anyone's opinion. That difference explains why one side of this market can fall silent and the other cannot. A trader facing a thin, unfavorable market can do nothing, and doing nothing is exactly right. A miner has no such option. The electricity bill arrives whether or not the market is watching, so a miner still producing at a margin keeps selling at whatever price exists, as long as covering that bill beats failing to cover it. Coins can go completely quiet. A working miner never quite can.

A holder underwater has little reason to sell into a thinning market, since selling locks in a loss that might evaporate in six months. A holder slightly ahead has little reason either, since a thin market cannot absorb the sale

without moving price against them. Both reach the same conclusion from opposite directions. Hold.

A second reason sits underneath the thin market. Subtract fees and friction from a small gain and it nets almost nothing, so selling and holding land in the same place, and the trouble of selling wins nobody anything. A loss carries no such symmetry. Sell it and it becomes permanent. Hold it and a possibility stays open that a quiet market can neither confirm nor kill. That asymmetry alone, without conviction, without faith in recovery, keeps most holders still.

What Comes Next

Both markets reach the same stillness by different routes. One ran out of willing traders on either side. The other is held there by a physical cost that keeps one party selling whatever the price. Neither is panic. Both are what people do when there is nothing left to gain by moving.

What that stillness settles, mechanically, takes a chapter of its own.

CHAPTER THREE (B)

What the Stillness Decides

Two markets have gone quiet for two different reasons. Here is what the quiet settles

COLD COINS, COLD ASICS · THE FIRST BOTTOM, CONTINUED

Stillness is not the end of anything. It is the moment two things get decided, one about scarcity and one about cost, and both are worth following precisely.

Where the Two Vectors Cross

Here is the structural definition of a bottom this book uses throughout. Market supply, meaning coins somebody will actually sell right now, keeps shrinking as holding rises. Demand need not grow at all for something to happen. It only needs to stop shrinking faster than supply.

At some point the two cross. Remaining demand exceeds remaining willing supply. Two kinds of scarcity operate here, and collapsing them into one word breeds confusion. Structural scarcity is fixed at the protocol level: how hard, measured in effort over time, increasing the total stock happens to be. A hard-capped coin carries this from launch, whether or not anybody notices. Local scarcity is a live market condition, demand exceeding what sellers will part with at the current price, and that begins here, at the crossing, not before. A coin can carry structural scarcity for years while its local supply and demand sit in abundance throughout. What shifts at the bottom is the local condition, never the structural one.

Where does that specific price come from? Not from search or negotiation. Fix the marginal machine and the electricity rate it runs on, and the cost of producing one coin is settled mathematically before the market arrives at it. Hashrate falls alongside price and issuance, but the joules per coin do not move on that account. They were set when the marginal machine was set. While market price sits above that number, freshly minted coins arrive as forced sellers, undercutting the market whether their owners like it or not. The pressure continues until one of two things happens. Demand outgrows what the selling can absorb, or price falls the rest of the way to a floor decided before the fall began.

Picture one coin at two moments years apart, at the genesis this book opened on and again deep into a long bear market. Structural scarcity is identical across both. The local condition is not. At genesis, almost nothing circulates and almost nobody sells, so price climbs hard on thin supply. Deep in the bear, holders accumulate quietly, sellers are scarce, price sits flat or drifts down, and local supply exceeds local demand. The coin was structurally scarce every day of that stretch. It also spent years abundant by the only measure that moves price.

Two Kinds of Compression

Two separate forces close this gap, and only one belongs to the story so far.

While the gap widened, dollar cost of production rose and machines got expensive, exactly as the last two chapters described. Now the gap peaks and begins closing, and dollar cost compresses back down. Notice what does not happen. The physical joule cost of the machine doing the mining stays put. Same machine, same electricity price, same joules per coin. What compresses is the price built up around it, bid back down as more operators chase an unchanged opportunity.

The distinction is not merely theoretical. Buyers of a popular machine near a peak paid prices weighted heavily toward capex, with upfront cost dominating, on a payback timeline assuming elevated revenue would hold. It did not hold, and payback stretched far past what the purchase assumed. The same machine bought near the following bottom, at a

fraction of peak price, carried a smaller capex share and a longer projected payback on paper, then recovered faster once conditions improved. The machine never changed. Its efficiency was identical at both prices. Only what the market would pay for it moved, and it moved enormously, while the physical number underneath held still.

That unchanging physical number has a name, and this is the place to pin it down, since the term appears constantly from here on. The joule floor is the energy a single machine spends to do one unit of work. Which machine? Not the weakest one still hanging on, and not the best one that exists anywhere. The one that beats every rival on total cost, purchase price and running cost together. Capital swarms whichever machine wins that comparison, so that machine ends up doing most of the work on the network, and its energy cost is what producing a coin actually costs at scale.

Plainly, then. The joule floor is what one machine spends to do one unit of work. Joules per coin is what the whole network spends to produce one coin. Only the first is a floor. The second can climb while the first keeps falling.

Those two numbers differ because a second thing sits between them: how much total work the network demands for each coin it releases. Add machines and that demand rises, since every coin now stands behind more competing effort. Cut issuance and it rises again, since the same work is spread across fewer coins. Multiply that demand by what one machine spends per unit of work and you have the energy behind a coin. Efficiency pulls the number down. Everything else pushes it up.

> *A better machine existing changes nothing. The floor moves when a better machine becomes cheaper to own and run than the one already there.*

Here two mechanisms hand off. Fast, reversible, competitive compression, the same machine getting cheaper as rivals bid its price down, is still the local story this book has told from the beginning. Slow compression, where the floor steps onto a better machine, has not happened yet. It also does not happen on its own. Better hardware can exist for a long stretch and move nothing, because a cheap secondhand machine is a hard thing to beat on total cost. The floor waits, then drops in one motion when the challenger finally wins that comparison.

One caution about that step, because it is easy to take the wrong lesson from it. A better machine lowers what one machine spends per unit of work. It does not lower what a coin costs to produce, and usually does the opposite, because the machine that lowered the figure also attracted the competitors who raise it. Watch the two separately from here on. The energy behind one unit of work falls. The energy behind one coin climbs.

Two Stillnesses, One Bottom

The bottom is not one event but two stillnesses landing near each other. Hardware stops moving because both sides ran out of reasons to trade. Coins stop moving because both sides reached identical conclusions from opposite directions. Underneath, supply and demand finally cross for the first time since the mania started.

This is the hinge the whole book turns on, and it deserves marking rather than passing as another chapter. Everything up to here has been local: machines, manufacturers, a used market, one cycle spinning through its phases. What comes next is not. The floor this bottom leaves behind does not reset for the next cycle to spin around. When it moves it moves one way, and it never moves back.

CHAPTER FOUR

A Little Demand Goes a Long Way

At the bottom, holding was the only rational choice. Now it starts to matter that almost everyone made the same one

The last chapter left coin and hardware markets both still, for the same reason. Nobody on either side gained anything by moving. Balance like that does not last, and tipping it takes almost nothing.

A Thin Market Moves Easily

Market supply, remember, differs from total coins in existence. It counts only what somebody will sell right now. At the bottom, willing supply had shrunk to almost nothing, since nearly every holder had reached the same verdict. Selling here gains you nothing.

A market this thin needs little demand to move. Slightly more buying than the trickle of selling still happening, and price rises. Nothing dramatic has changed. Almost nothing stands in the way.

Holding Was Already the Default

Nobody adopted holding as a strategy in response to rising price. It was the rational default at the bottom, before any of this began, for reasons unconnected to expecting recovery. A holder underwater had no reason to sell into a thin falling market. A holder slightly ahead had no reason either, since the market could not absorb the sale without moving price against them.

So price begins rising against a population already positioned to hold. Price enjoys an advantage here it will not have again later in the cycle. Almost nobody waits to sell into the first sign of strength, because almost everybody arrived committed to waiting.

> *The stillness that made the bottom quiet is what makes the recovery outrun the fall.*

The Miners Stop Selling So Much

Something else shifts as price lifts off the floor, and it works against the market finding a ceiling. At the bottom, a miner at the margin had to sell nearly everything mined, because the electricity bill consumed nearly everything a coin was worth. Lift price and that stops being true. The same bill now takes a smaller share of what the same machine earns, so a smaller share of production has to be sold to cover it. Miners begin keeping some.

Consider what that does to a market already short of sellers. The steadiest source of new supply is the one that cannot stop selling, and it has just started selling less. Holders were already unwilling. Now the one participant with no choice in the matter needs the market less than it did last month. Supply tightens exactly when demand is picking up, and price rises further, which tightens it again.

> *Rising price does not draw sellers out. It excuses the only forced seller from having to be one.*

The loop does not run forever. Somewhere above, price gets high enough that coins bought or mined cycles ago become worth releasing, and the market floods with old supply that no bill obliged anybody to sell. That is a later chapter. What matters here is that the same mechanism runs in

reverse on the way down. Falling price forces miners to sell a larger share to cover the same bill, adding supply precisely when the market can least absorb it, which pushes price down and forces the share higher again. The descent has its own amplifier, and it is the same one.

What This Does to the Hardware Side

The thinness that makes the coin responsive works on the mining side too. At the bottom, used hardware had settled at marginal cost with almost nothing changing hands. As price climbs, even slight improvement in profitability makes the idle machines from the last chapter worth switching back on.

No new hardware need arrive. The infrastructure never left. It kept mining while the market around it went silent. What changes is how much of it justifies running at the current price, and that number climbs the moment price does.

What This Sets Up

The climb out starts quietly and starts easily, because almost nothing remains in its way. A little demand moves a thin market. A population committed to holding does not interrupt it. Idle machines earn their keep again without anybody building anything.

Quiet does not last. The next chapter follows what happens once mining turns genuinely attractive again and new hardware, not merely the survivors, starts arriving.

CHAPTER FIVE

Mining Is Fun Again

The machines that get built now cost more than the ones they replace, and everyone paying that price knows exactly why

The last chapter left price rising against a thin market and idle machines switching back on as profitability returned. This chapter picks up where idle capacity stops being enough.

Old Machines Run Out of Room

The machines still standing were built for a different, lower price. As price climbs they earn more, but a hard limit caps how much more. The hardware has a fixed physical ceiling on output, however profitable running it becomes.

Once enough machines press against that ceiling, capturing more of a widening gap requires new hardware rather than more of the old. New machines arrive here, not because the last generation failed, but because it has done everything it can.

Built for a Market That Has Already Moved

Worth asking where these machines came from, because they did not appear on demand. Somebody committed to building them months earlier,

and committed against the conditions visible at that moment rather than the ones waiting at the far end of the production line.

Those decisions are not made evenly across the cycle. Deep in the bear, with nobody buying hardware at any price, the case for taping out a new design collapses and the pipeline empties. It refills only once buyers reappear, which means the machines arriving into a recovering market were specified against a market that was still on the floor. Lower price. Higher issuance. Grimmer assumptions throughout.

Which is why they land so well. Silicon improves whether or not the market cooperates, so whatever finally ships is more capable than what it replaces, and it arrives into conditions better than the ones it was designed for. A manufacturer holding that combination can ask a premium and get it. The buyer still comes out ahead, measured against running the older machine another season.

> *Nothing was timed. The pipeline emptied when nobody was buying and refilled when they returned, and the lag did the rest.*

One thing moves against the buyer through all of this, quietly and without exception. Issuance only ever trends down. A machine specified when the protocol released coins at one rate arrives when the rate is lower, and spends its working life watching it fall further. Every machine ever built has earned fewer coins than the conditions of its design implied, and every machine ever built always will.

A Shorter Payback Is Worth Paying More For

Here is the mechanical heart of the chapter. Rising profitability means a machine pays for itself faster than before. A shortening payback period signals, visibly and calculably, that the machine is underpriced against what it earns.

A manufacturer watching that signal has direct reason to raise price. Not greed. A buyer facing a shorter payback can afford more upfront and still come out ahead. Price rises to meet the opportunity, dragging the

payback period back toward whatever buyers accept, typically near a year at whatever rate the most competitive miner pays for electricity.

> *A shorter payback does not stay short. The market prices it back toward the waiting period it always settles near, at a higher cost of entry.*

Notice who is buying, though, because it is not only the careful operator working the numbers. A wide gap pulls in people who want the machine paid off in a season, not across a year, and they are frequently the ones with the worst power contracts and the least room for anything to go wrong. That combination sounds irrational and is not. A short payback is precisely what protects a weak position. Get the capital back before conditions turn and the rest is profit; miss and the machine was never survivable anyway.

So the bidding for new hardware is led by the miners who can least afford to be patient. They will pay a steep premium on the purchase price for a credible chance of fast repayment, because speed is worth more to them than price. Which is how capex climbs faster than efficiency alone would justify, and why the machines command what they command during the good stretch.

> *The buyer paying most for a machine is often the one who can least afford to wait for it.*

Capex-Heavy in the Good Days

That has a direct consequence for what mining costs during such a stretch. Total cost of producing a coin splits in two: what the machine cost to buy, and what it costs to run. Here the machine price rises while electricity holds roughly steady. The balance tips capex-heavy, with a larger share of total cost sitting in the purchase and a smaller share in the monthly bill.

Later, this book shows the balance reversing outright, once the cycle turns and capex collapses toward its floor while electricity resumes dominating.

The Network Breathes Out

A widening gap has a further consequence, and it explains something about the network rather than merely its cost of production.

A miner deciding whether to run a machine watches more than one number. ASIC price, electricity cost, block reward, and difficulty all move, and none move in step, each lagging the others by a different interval. Wide enough profitability makes that matter less. A broader range of operating conditions turns viable at once. A miner paying more for power, or running older hardware, can profit alongside the most efficient operators alive.

This cuts against the instinct that a bull market rewards whoever is already most efficient. On average it does the opposite, even while the marginal floor stays anchored to the same efficient machine described earlier. The floor holds. The population mining above it widens, diversifies, and grows less efficient on average, because a broader range of conditions can clear it.

> *The best miner does not get worse. The average one does, because the bar dropped low enough for a great many others to clear.*

A wider, more varied population, spread across more power sources and more locations, is a more decentralized network. Mechanical consequence, not coincidence. As the gap closes again, the weakest of that widened population get pushed out first, concentrating hashrate among fewer, better operators. One thing more. The bear that follows does not return to the concentration of the last one, since the floor has stepped down by then onto a better machine. Each bear runs more concentrated than the bull before it, and less concentrated than the bear before that.

A Third Real Cost: Time

A third cost sits apart from the machine price and the electricity it burns. How long the buyer waits before the machine pays for itself, and what can go wrong meanwhile.

A miner buying now, at an elevated price, carries an exposure earlier buyers avoided. If difficulty keeps climbing while payback runs, as more of the same attractive hardware comes online, the return falls short of what the purchase assumed. Paying more upfront for a shorter expected wait only pays if the wait stays short. Time here is a risk taken on, not a delay tolerated.

What Follows

So mining turns attractive again, new machines arrive expensive, and cost shifts toward capex while it lasts. Everyone paying those prices does so with open eyes, since the shortened payback justifying the price is exactly what a rising market just made visible to everybody at once.

What happens next has already happened before, earlier in this same story. Notice the resemblance when it arrives.

CHAPTER SIX

The Rhyme

Set the last chapter beside this one. Notice what repeats, then notice what does not

New machines arrived expensive and a wider, more varied population of miners spread across the network while the gap stayed open. That cannot run forever. What follows is not new, and the chapter it repeats is not the one just finished. Look further back, to the moment hashrate first caught price and overran it, coins turning cold while the machines chasing them still ran hot. That phase is about to happen again.

Selling to Beat the Competition, Again

Somewhere in this climb, the logic that opened the story returns. Coins get sold to fund machines. Machines get sold to fund a faster exit. The profitability gap, wherever it sits, is visible to everyone simultaneously, and nobody wants to be the miner still deliberating after everyone else has moved.

Same mechanism as earlier chapters, not a new one. Follow the miners. When hashrate outgrows price by a meaningful margin, that growth is itself the signal the gap is closing, and closing gaps get sold into before they finish, never after.

> *Sell some coins to beat the competition. Which, of course, is exactly what opened this story in the first place.*

What Rhymes, and What Doesn't

Reading this as the same event twice would be a mistake. What changed since the pattern first appeared matters more than what held.

The machines being sold now differ from the first cycle's. Newer, more efficient, bought at a higher price during this particular climb. The population of miners differs too, widened by exactly the process the last chapter described, and due to narrow again as its least efficient members exit first once the gap closes. And the marginal machine's cost of survival, the floor beneath all of it, has stepped down since the last time this played out, whatever the coin's full joule cost happens to be doing above it.

List what actually differs and the rhyme sharpens. The population selling into this gap is larger than the one that sold into the last, because the wider, more varied field that entered during the climb has not fully thinned yet. The machines they hold were specified during the previous bear, when nobody was buying and the pipeline had emptied, so they were built against grimmer assumptions and arrived into better ones. Issuance is lower than it was, so every one of those machines earns fewer coins per unit of work than its design implied. And the coins being sold are drawn from a shallower pool, because a portion of what went into storage at the last bottom never came back out.

None of that changes the shape. All of it changes the size. More machines chasing fewer coins, sold by more operators into a market holding less loose supply than last time. The gap closes the way it always closes, but everything doing the closing has grown.

Hence a rhyme rather than a repeat. The shape is recognizable. Nothing inside it is identical.

The Same Gap, Doing the Same Work

A structural reason drives the recurrence, not a quirk of psychology. A wide, visible profitability gap does not survive because people miss it. It dies because they see it, and everyone killing it, selling coins, selling hardware, entering as a new miner, does what killed the last one, though the crowd doing it, and its size, differ every time.

No flaw in the mechanism. That is the mechanism, running again, because the conditions that produced it the first time have returned in a higher but structurally identical form.

Same Shape, New Turn

So the rhyme closes as the first cycle did, coins and machines both sold to capture a gap everyone can see closing. What follows is familiar too. A quiet bottom, both markets going still.

The question this book has built toward is not whether that bottom arrives. It always arrives. The question is where it lands relative to the last one.

CHAPTER SEVEN

A Higher Low

The cycle looks the same from the inside. It is not the same from above

The rhyme closed with coins and machines sold into a gap everyone could see closing, the pattern that opened this story. What follows is familiar too. Fast competitive compression, then quiet, both markets going still together, exactly as described earlier.

Here it pays to stop watching the cycle from inside and look at where it landed.

Same Shape, Different Floor

From inside, the second bottom feels exactly like the first. Volume drops. Holding rises. Used hardware goes quiet at whatever marginal cost has become. Nothing about the experience announces a difference.

Something is different anyway, and it is not what most people reach for. The usual answer is that the hardware improved, and it did. Better machines took over during the climb, spending less energy for the same work than anything running a cycle earlier. Left alone, that would make coins cheaper to produce and push this bottom lower than the last one.

The hardware was not left alone. Every improvement drew more machines in, and the protocol released fewer coins across the same stretch, so the work standing behind a single coin rose on both counts while the machines doing it got better. Those two forces run against each other and one of them wins. Competition compounds without pause. Efficiency arrives in occasional steps and is bounded by what can be built. Over a

full turn of the cycle the competition outruns the silicon, and a coin ends up costing more energy to produce than it did a cycle ago, not less.

> *The bottom feels the same because the story around it is the same. It lands somewhere different because the machine underneath it already changed.*

Measuring It From the Top

That is the whole of it. Production cost is a floor under price, and the floor is higher than it was. The bottom lands higher because coins genuinely became more expensive to make, not despite the hardware improving but because of what the improvement attracted.

Now take each bottom in turn. The second need not match the first bottom's price to count as progress. It needs only to sit at or near the second cycle's lower joule floor, the marginal machine's cost, a physical fact rather than a hope. Measured against the machine's floor rather than the previous cycle's price, you can see honestly whether progress happened.

The Same Floor, Reached by More People

Something else deserves saying about a second bottom, because the phrase higher low can mislead about what actually recurs.

The condition at the bottom is the same condition every time. Miners at the margin covering their power and nothing else. Holders split near evenly between profit and loss, neither half with a reason to move. Hardware trading at whatever the marginal machine can justify. That state does not improve. It is what a bottom is, and every cycle returns to it exactly.

What grows is the scale of what arrives there. More machines reaching it. More operators reaching it. More total energy having been spent to produce coins that are fewer in number than the ones the previous cycle

produced. The floor is not higher because the condition got easier. It is higher because a larger, hungrier system now has to be fed before that same condition can be reached at all.

> *Every bear ends in the same place. It just takes more of everything to get there.*

Both ratchets show up in that sentence, doing different work. The rising cost of production is why the floor sits where it does. The rising base of held coins is why fewer of them are available to push it back down. One raises the bar and the other thins what could be thrown at it, and neither undoes itself when the cycle turns.

Why This Is Not an Accident

It keeps happening for a specific reason, not luck. Competition can bid a machine's price up and down as often as a gap opens and closes, and that motion reverses freely. What does not reverse is the accumulated work standing behind a coin. Machines that entered during the climb do not un-enter when price falls, they run until they stop paying, and issuance never returns to an earlier rate. So the effort behind a coin holds its ground through the fall and starts the next climb from there.

Here is the honest sense in which both halves of this book's title apply, each to its own half of the story. The fast, repeating part, coins and machines changing hands while gaps open and close, behaves like an engine. Cycling, reversible, returning near its start each time. The slow part behaves like a ratchet, permitting motion one way only, and what moves that way is the cost of producing a coin. It climbs. Better machines arrive and push against it, and lose, because every improvement pulls in more competitors than it displaces.

Where This Goes

So the second bottom lands higher, neither by luck nor by design, but because the fast part ran its course while the slow part quietly did what it always does. Carry that forward as the central claim of everything after. The story repeats. The floor beneath it does not.

Having watched it happen once, go back and measure what moved, and by how much.

CHAPTER EIGHT

Clearing the Picture

Everything in the last seven chapters, said again, in four phases and two ratchets

Eight chapters have walked one full turn of this story, plus enough of a second to prove where it lands. What follows compresses the shape into a single pass, naming each phase and filling in two things that were true throughout but never said outright.

Hot Coins, Hot ASICs

Start at the top, where both sides run hot at once. This happened once as genesis, the first time price ever met a mining cost, with machines already spinning before anyone quoted a number. It has happened at every peak since for ordinary reasons, and those are the ones to trace.

New machines arrive in volume. Competition among manufacturers sharpens, since several shipped into the same opportunity. Coins sell for two distinct reasons at once, traders taking profit and miners converting coins into machines to chase more of the same reward. Whatever drives any single sale, redistribution starts here, coins moving from wherever they sat toward wherever the opportunity is.

Inside this phase sits the stretch people mean when they say bull run.

Picture the climb as one continuous curve rather than a series of jumps. Price starts slow, building as any trend does before outsiders pay

attention. What this book calls the bull run is not the whole climb. It is the steepest, most vertical stretch, where mining capacity has hit its constraint and buying the coin is the only lever left. What follows, once new hardware lands, is the same curve easing off its peak angle.

A moment of its own, distinct from what came before. Used hardware thins as available machines get bought. New orders pile up, but a physical lag separates ordering, manufacturing, and shipping, and that lag does not shrink because demand grew. For a stretch, hashrate cannot grow as fast as appetite for it.

During that stretch one route to exposure remains. Buy the coin directly on the open market. That is the engine behind what people call the bull run, and it happens here rather than elsewhere in the cycle for an exact reason. Demand arrives faster than mining capacity can answer.

The lag has one further effect on new-machine pricing. Whoever ships working units into this stretch first becomes the price-setter, briefly, since every rival still has product in transit or on the line. That first price is what the rest must compete against when their shipments land.

> *For a while, there is only one lever left to pull. Everyone pulls it at once.*

Cold Coins, Hot ASICs

Price stalls, then slides. Hardware ordered during the lag catches up to the opportunity that justified it and then overshoots, hashrate racing upward while the reward stops growing. Difficulty rises to match, pushing the least efficient of the widened population back out. ASIC prices fall, new and used alike. Cost tips back from capex toward opex, the reversal described earlier.

Cold Coins, Cold ASICs

Both markets go quiet. The bottom, described at length already. Two stillnesses landing together, coins because nobody has reason to move them, hardware because both sides ran out of reasons to trade.

Two markets absorb the excess a hot phase throws off, not one. Secondhand machines soak up the hardware, capital and urgency, the role already described. Held coins do the same on the other side. Through the climb, holding thins out and trading volume swells, and that volume is the coin market running hot. It cools by draining back into storage, and volume falls as it goes. Note the asymmetry between the two. New machines can flood a market, arriving in bulk from every manufacturer at once. Newly issued coins never can, since the protocol releases them at a rate no one can hurry. Only coins already held can flood, and only if price offers enough to pull them out.

Hot Coins, Cold ASICs

The cycle closes where it reopens. Machines that survived the bottom sit cold and idle, not yet worth switching on, while the coin starts moving before they do.

Coin price rises. Profitability follows at once, since the same running cost now earns more. It surfaces first as a shortening payback, a machine covering itself faster than expected, long before anybody builds anything.

After a short lag, the shortened payback makes idle and used hardware interesting again, and prices for both used and new units get bid up as more people notice the widening gap.

Two Ratchets

Neither ratchet is a fifth phase beside the other four. They run underneath all of them, at different speeds. Hardware improves in discrete jumps, and only when a newer machine beats the incumbent on total cost, purchase price and running cost together, which a cheap secondhand machine can hold off for a long time. Competition never waits for a clean moment. It grinds on continuously, and holding accumulates without pause, a little more staying put at every bottom. The cycle keeps

returning to the same four shapes. What sits underneath them does not return to anything.

Two mechanisms in this book earn the word ratchet, one on each side of the market, and neither collapses into the other.

The first sits on the mining side: what it costs to produce a coin climbs, cycle after cycle, and never returns to where it was. Two forces decide that number and they pull against each other. Better hardware pushes it down, arriving in occasional jumps, bounded by what can physically be built and by whether anyone will fund building it. Competition pushes it up without pause, because every machine added means more work standing behind each coin, and every reduction in issuance means the same work is divided among fewer of them.

Competition wins that contest. Not in any single moment, and not always within one cycle, but across full turns of the wheel it outruns what silicon can deliver. A machine improving twice over means nothing if the ocean it mines against has more than doubled. So the direction holds: fewer coins produced, more effort chasing each one, and every coin on average harder to make than the last. There is always a bigger fish. This is the ratchet, and it pays to be exact about what does the ratcheting. Not the hardware, which only ever helps. The competition it attracts.

The second sits on the coin side. At every bottom, cost basis straddles current price, roughly half the circulating coins in profit and half underwater, each half holding for its own separate reason. Holding jumps here, and it never fully unwinds when price recovers. Some portion of what crossed into long-term storage at that moment stays there, gone from circulation, the pattern visible in how rarely the oldest coins ever move again. Not physical, not mechanical, real regardless, and pointing where the first points: one more thing the local cycle produces that never comes back.

> *One ratchet makes each coin harder to produce. The other makes fewer of them available to buy. Both only move one way.*

Both run together, and they compound rather than cancel. One raises what a coin costs to make. The other shrinks what is available to buy.

Neither reverses when the cycle turns, which is why the next bottom cannot land where the last one did.

The Story Ends Here

That closes the story half of this book. Every mechanism named across these eight chapters, forced convergence, the used-hardware market, the two forms of compression, the two ratchets, has been described in words, with no number attached to any of it.

Which Networks This Describes

One caution before the numbers arrive, because the preceding chapters have said nothing about which networks any of this applies to, and silence there could be read as saying it applies to all of them equally. It does not.

Every proof-of-work network has something engine-shaped in it. Demand on one side, cost of production on the other, work extracted from the distance between. That much comes with the design. What differs is how much of the work survives the trip, and the differences are large enough that two networks running identical machinery can produce quite unequal money.

A supply cap is the version of this everybody knows, and it is the least interesting one. Debasement does not require printing. Work spent on blocks that lose the race is spent all the same and secures nothing, a leak measured in wasted joules rather than issued units. Rewards that route through concentrated intermediaries arrive lighter than they left. Launches that hand a share to insiders before anyone else can compete distort the price signal at the point it was supposed to be born. None of that shows up in a supply schedule, and all of it erodes what the money is.

> *A hard cap tells you nothing about how much of the work is reaching the other side.*

This book takes the sound case and follows it carefully, because a mechanism is easiest to see where it runs cleanly. It makes no attempt to

catalogue the ways a network can be less sound, which is a large subject with a shape of its own. Anyone wanting that catalogue will find it in The Instrument, under Degrees of Soundness, where the leaks are named individually and measured against each other rather than lumped under a single word.

So read what follows as describing networks whose machinery is intact. Where it is not, the same parts are present and some of the output goes missing on the way out.

The next part puts numbers to it.

PART TWO

The Mechanism

The same story, now given units

Everything in this part assumes the block reward is the only revenue a miner receives. That is true for now. The final part shows what happens once a second revenue stream, transaction fees, begins to matter, and how that changes the shape of everything described here.

CHAPTER NINE

What a Machine Makes, What a Coin Takes

Everything in the last eight chapters happened in words. This chapter supplies the unit

A joule is a small amount of energy. A kettle pulls roughly two thousand every second it runs. A phone charging overnight consumes a few tens of thousands. A mining machine, left going for a day, burns hundreds of millions.

Part One was built from this unit throughout. Time to say so.

What a Machine Makes

Machine efficiency gets measured in joules per unit of work, the energy spent performing one hash. Two machines can look alike and differ enormously on that number, and the number explains why chapters two, six, and nine behaved as they did. A more efficient machine does identical work for less energy, so it can sell output cheaper and still profit. Which machine wins the used market, which one a manufacturer prices aggressively, which becomes the marginal producer, all of it traces to this single figure.

A physical property of the hardware, not a sentiment. It does not shift because the market turns excited or afraid. A machine built to spend a given number of joules per hash spends exactly that, bull or bear, until something better physically replaces it.

What a Coin Takes

Scale that number to the network and a second figure appears. Joules per coin, the total energy spent producing one unit of what the network issues.

Not merely machine efficiency times some constant. It depends on how hard the network currently makes the puzzle, which depends on how much hashrate competes, which depends, as Part One showed at length, on price. Joules per coin is where fixed efficiency meets moving difficulty.

> *A machine's efficiency is fixed the day it is built. What the network pays for a coin is fixed by nothing, until one machine becomes the one nobody can undercut.*

The Marginal Machine Sets the Real Number

At any moment, machines of many ages and efficiencies mine simultaneously. The number that matters here is not their average. It is the efficiency of whichever machine sits at the edge, the worst one still turning a profit at current price and current power cost.

Assuming the most efficient machine sets the price is easy and wrong. The best machine earns the widest margin, nothing more. The marginal machine, the worst one still standing, anchors what the network effectively pays to produce a coin. Push price below what it survives on and it exits. The marginal machine changes, and the network's cost changes with it.

Efficiency alone does not define the marginal machine. Two miners on identical hardware face wildly different outcomes if one pays three cents per kilowatt-hour and the other twelve. Cheap power tolerates a worse machine. Expensive power demands a better one to stay level. The marginal position comes from the combination, and whichever miner is weakest on both is the one whose exit moves the number.

The Machine Has a Joule Cost of Its Own

So far this chapter counts only the energy a machine spends while running. Half the picture.

A machine already sitting in a warehouse costs pure opex, whatever it burns from here forward. Nobody starts there. Somebody built it first, and building was not free. Refining silicon, etching it into a working chip, assembling the board, all of it consumes energy long before the machine hashes anything.

Not a rounding error. If a machine trades near its manufacturing cost, the convergence already described for coins, price settling toward physical cost once competition strips the excess, applies here as well, one level upstream. Building a machine and running one draw from the same well. Not two kinds of spending. Two stages of the same production.

> *Mining a coin is brute-forcing a hash until one satisfies a condition. Building the machine that does the mining is refining raw material into ordered structure, one careful layer at a time. Both are production. Both cost joules. Neither is free.*

So the complete joule cost of one coin exceeds the energy spent running the marginal machine. Add a share of whatever energy built it, spread across every coin it will produce in its working life. Skip that and the figure describes only somebody who already owns hardware. Include it and it describes what entering from nothing costs.

Which raises the obvious question. Spread across how long?

A working life is not a specification printed on the box. Nothing wears out on schedule. A machine stops working when it stops paying, the moment what it earns no longer covers the power it draws, and that moment is decided by the cycle rather than by the hardware. Bought into a widening gap, a machine runs for years. Bought into a closing one, it can stop paying inside a season. Identical silicon, wildly different divisors.

There is a cleaner way to mark the endpoint. A machine that cannot cover its own power is worth nothing to anybody else either, since whoever

bought it would face the same bill. So the working life runs from purchase until resale value reaches zero, and the used market sets that date, not the manufacturer. However many coins come out across that span is the divisor, and the whole of the manufacturing energy is spread across it.

Run that to its conclusion and something tidy falls out. A miner paying the network average for electricity, from purchase until the machine is worth nothing, puts in a total that matches what comes out. Capex plus opex on one side, coins received on the other. Cheaper power and they keep the difference. Dearer power and they are funding somebody else who keeps it.

Doing the Actual Arithmetic

The calculation has two parts. First, take the marginal machine's efficiency in joules per unit of work, take current difficulty, multiply. That gives running cost, the opex half. Second, take the joules that built the machine and divide across the coins it will produce. Sum them for the complete joules-per-coin figure, at this moment, for this network, given whichever machine sits at the edge.

Convert to money and it gets more concrete still. A kilowatt-hour holds 3.6 million joules. Divide joules per coin by that, multiply by the electricity price, and you have dollars. What producing one coin costs right now.

What That Number Obliges

Fix the marginal machine and the electricity it runs on, and the cost of producing a coin stops being a question. Both halves are settled. So many joules, and so many dollars for those joules. Nothing about a falling market changes either figure, and nothing about a rising one does either. The number sits there waiting, decided before the market arrives at it.

What the market decides is how much of the production a miner is obliged to sell. A miner is not choosing between selling and holding out of temperament. Electricity is billed continuously and the bill does not wait. Coins get sold to cover it, and the only question is what fraction that takes.

Hold price well above the cost of production and the fraction is small. A miner covers the bill with part of what they mine and keeps the rest, and plenty do exactly that. Let price fall toward the cost of production and the fraction climbs, because the same bill now consumes more of what the same machine earns. At the floor, the miner sitting at the margin has no fraction left to withhold. Close to everything mined has to go, immediately, simply to keep the machines running.

> *Nobody at the margin is choosing to sell. They are selling because the alternative is switching off.*

Which sets a ceiling on how much selling the network can produce. A miner cannot sell more than exists to be sold, and what exists is whatever the protocol released. When price sits at the cost of production, essentially all of that new issuance reaches the market and the pressure is at its maximum. That maximum is not fixed, though. Issuance shrinks on a schedule no one controls, so the largest forced sale the network is capable of gets smaller with every cycle. The pressure that defined earlier bottoms cannot define later ones with the same force.

The Real Numbers

That single calculation drives everything Part One described in words. The gap opening, the crash, the stillness, the recovery, all of it was this number moving, or price failing to keep pace with it.

The next chapter breaks that dollar figure apart into its own pieces, since paying for a machine and paying to run it are not the same kind of cost, and neither of them is the same as the cost of simply having to wait.

CHAPTER TEN

Capex, Opex, and the Cost of Waiting

Two of these three costs are the same currency, paid on different schedules. The third is a different currency entirely

The last chapter showed that manufacturing a machine consumes energy, the identical kind of cost as running it. This chapter follows that to its conclusion, then adds the one cost energy alone cannot explain.

Opex Paid Upfront

Capex is not a separate category sitting outside this book's logic. It is opex, paid in advance.

Every dollar that went into building a machine, refining silicon, assembling the board, shipping it, is energy somebody already spent, bundled into one price and handed over at once. The buyer is not purchasing a different kind of cost from the electricity bill that follows. Same cost, already paid, on a different schedule.

That leaves a miner one choice this book has not yet named. How much of the total to pay now, how much later. An expensive, efficient machine bets on more upfront and less over time. A cheap, inefficient one bets the other way, less now, more spread across every future kilowatt-hour. Both can land near the same total, drawing from the same well.

> *A miner is negotiating with the network over one total. The only question capex and opex settle between them is timing.*

Two Premiums, Not One

Once that lands, a temptation appears: treat every price above physical cost identically, coin and machine alike. Resist it. A useful distinction sits underneath.

When a coin trades above its joule cost, the premium is a direct bet. An outside buyer with no stake in mining pays more than physical cost because they expect the coin scarcer, or more valuable, later. Mining explains none of it. The premium arrives from outside the system.

When a machine trades above its manufacturing cost during the same bull phase, something else drives it. The buyer is not betting the machine is scarce in any lasting way. More can always be built. The buyer is betting on the coin's premium and bidding up the machine because it is the fastest tool for capturing that bet before somebody else does. The machine's premium is real but not original to it. Inherited secondhand from the coin, transmitted by competitive urgency, the willingness to overpay simply to arrive first.

One premium is direct, the other derived. Coin scarcity funds machine scarcity, never the reverse, and the distinction explains why an elevated machine price collapses faster than an elevated coin price. A derived bet unwinds the instant the thing it depends on stops paying. A direct bet can survive on belief long after.

A derived premium runs the other way too. When the coin's premium collapses, nothing independent holds the machine at its manufacturing cost. A desperate seller, still facing the continuous electricity bill described earlier, takes less than the machine cost to build simply to escape before the next bill. Briefly the machine becomes salvage, priced by what somebody will pay to be rid of it rather than by what it might earn.

The Cost Neither of These Explains

Capex and opex together cover every joule spent, upfront or over time. Neither covers something a miner takes on the moment they commit to either. How long the wait before that spending returns, and what can go wrong meanwhile.

A different kind of cost, measured in neither joules nor dollars but in risk carried across time. A miner paying up for a shorter expected payback only wins if the payback lands on schedule. Let difficulty keep climbing while payback runs, as more of the same hardware arrives behind them, and the return falls short of what the purchase assumed. The machine cost what it cost. The energy bought what it bought. Time turned against the buyer.

Picture a miner buying on a twelve-month payback. Let difficulty climb meaningfully across that year, as more of the same hardware lands behind them, and actual payback stretches well past twelve months. The purchase price has not changed. The electricity price has not changed. But now the miner carries months of extra exposure nobody priced at purchase: further price drops, hardware failure, a rising power rate. None of it appears in the capex figure or the opex figure. It appears only in how long the wait turns out to be.

What Remains

So producing one coin costs three things. Energy spent building the machine, energy spent running it, and risk carried across however long the first two take to repay. The first two share a currency. The third does not.

Notice what the third cost actually is, now that the second half of the calculation has a name. Manufacturing energy gets divided by however many coins a machine produces before it is worth nothing. Nobody knows that number at purchase. They estimate it, they pay a price built on the estimate, and the cycle decides afterward whether the estimate held. Time is not a vague unease about the future. It is the uncertainty sitting in a divisor that has already been committed to.

Calling it a risk undersells it. A risk is something that might happen. Every machine ever switched on has been running toward obsolescence from the first block it worked on, and the only open question is how fast. Somewhere a design is being taped out that will make this one uncompetitive. Somewhere hashrate is being added that will thin its share. Neither event needs to have happened yet for the machine to be worth less this month than last.

> *Nothing has to go wrong for a machine to be dying. It is dying on schedule, and the schedule is not published.*

What makes this bite is that the clock ignores the power switch. Idle a machine through a bad stretch and it keeps losing value at the same rate, because what erodes it is happening elsewhere, in fabs and in other people's deployments. Switching off saves the electricity and saves nothing else.

Which is why miners run at margins that look irrational from outside. A holder waiting out a weak market is holding something that will still be there afterward. A miner waiting out the same market is holding something that will be worth measurably less when it ends, and might be worth nothing. Waiting is not free for them and never was. It costs the machine. So they mine at thin margins, sell what the bill demands, and keep the thing earning while it still can, because the alternative is watching it expire quietly with nothing to show.

Both ratchets named in Part One run through this calculation, though only one appears in it directly. Rising production cost is the figure being calculated here, pushed up by difficulty as competition arrives and pulled down, more slowly, as better hardware takes over. The coin-side ratchet never enters the calculation at all, because it acts on how many coins reach the market rather than on what any of them cost to make.

Part Two closes here. What remains is the one force capable of shrinking the joule cost of a coin without anybody building a single new machine.

PART THREE

The Fee Correction

A second revenue stream, and what it changes

Everything that follows about fees is deduced from mechanisms already established, not observed at scale. No network drawn on in this book has yet run a sustained, high-fee regime long enough to test these claims directly. The logic is the logic confirmed elsewhere. The historical evidence, for this case, is not there yet.

CHAPTER ELEVEN

Racing With No Line to Jump

Congestion explains why a fee rises. It never explains why anyone was willing to pay one in the first place

What a Fee Actually Buys

Start with what changes when a fee is paid, because the rest of this part depends on it and it takes one paragraph.

A miner spends energy to find a block. Until now this book has treated the reward for that as one thing, the coins the protocol releases. A fee adds a second stream to the same block, paid by whoever wanted their transaction included, and the machine spent no extra energy earning it. Same joules, more value out. Divide the energy by the total and the cost behind each unit of value falls.

> *A fee does not make mining cheaper. It makes the same mining buy more.*

Which is the correction this part is named for. Part Two built the cost of a coin from the energy behind it and treated issuance as the whole reward. That was accurate and incomplete. Where fees are trivial the omission costs nothing. Where they are not, the figure understates what a network can pay for its own security, and by the time issuance has faded to nothing the omission is the entire picture.

Two warnings before going further. This is a local effect, not a change in the floor. Better-paid mining attracts more mining, difficulty answers, and the advantage erodes the way every advantage in this book erodes. And

fees are not free money arriving from nowhere. Somebody paid them, on purpose, for something they valued more than the fee. Which raises the question the rest of this chapter answers.

The last chapter set out how a fee market behaves once a network fills up. Set that aside. Several users can compete hard for priority while the network sits nowhere near full, each racing the others rather than racing capacity. Congestion has nothing to do with it.

Four Real Reasons to Pay

Urgency of this kind sorts into distinct shapes, and each deserves a name rather than being lumped into one undifferentiated feeling.

Asymmetric information: someone knows what the rest of the network does not, and pays to act before the knowledge spreads. A price is about to move, news is about to land, and whoever settles first takes the advantage before it evaporates.

Asymmetric pricing: something is worth two different amounts in two places at once, and closing that distance first is the entire point. Arbitrage in general has this shape, a momentary mismatch that pays whoever arrives fastest and vanishes the instant enough people arrive.

Asymmetric utility: an opportunity exists that nowhere else offers, and arriving first is the whole reward. Five people chasing one limited thing will pay to outpace each other while fighting over none of the network's capacity. They are fighting over the thing.

Then a fourth, weaker but present: plain impatience. Unlike the first three it requires no edge, no closing window, no scarce opportunity. It requires an unresolved transaction and somebody who would rather stop waiting. It is the faintest of the four and the easiest to dismiss at small sizes, but it scales the way the others do not, tracking whatever sits pending. Nobody pays much to hurry a coffee. Plenty will pay to stop watching a large transfer sit unconfirmed.

> *Nobody pays a fee for a transaction unless they expect the transaction itself to be worth more than what the fee costs. Everything else is detail.*

The Same Urgency, Applied Twice

This is the competitive urgency that bid up machine prices earlier in the book. There, miners overpaid for hardware to capture a coin premium before a rival could. Here, someone pays a miner directly to settle one transaction ahead of another. Identical force, identical willingness to buy speed, pointed at a different decision.

A coffee buyer and a trading desk on the same network mark the range this spans. The coffee buyer faces no competitor, no closing window, nothing to race, and whatever faint impatience they feel barely registers against a small purchase. A desk holding a live arbitrage sits at the opposite pole, obliged to pay whatever winning costs, because losing costs more. Same network, same fee market. Only one of them is under pressure.

Beyond Motive

What Each One Is Worth

These four do not pay alike, and the difference matters more than the labels. The first three are bounded by the size of the prize. Nobody pays more to capture an edge than the edge is worth, so the fee has a ceiling and the ceiling moves with the opportunity. A thin arbitrage supports a thin fee. A large one supports a large fee, briefly, until somebody closes it.

Impatience has no such ceiling and no such floor. It scales with the size of what sits pending rather than with any contest, which makes it the steadiest of the four and the weakest at any given moment. It does not spike. It does not vanish when the opportunity closes, because there was

no opportunity. It is simply always there, a little of it, under everything else.

Put those together and a fee market has a shape. A quiet base of people who would rather not wait, with occasional sharp bids from whoever has an edge that expires. The base does not move much. The spikes do everything else.

So a fee market runs on an engine that needs no congestion. Each of these forms of urgency can appear on a network with room to spare, and each is an independent source of demand for going first.

Worth holding onto how much rests on this. While issuance continues, a network survives whatever its fee market does, because the protocol pays for security regardless. That arrangement expires. Issuance trends to nothing on a schedule no one can amend, and at the end of it the only thing left paying for security is whatever people voluntarily hand to miners for going first. Every reason in this chapter is a reason somebody might do that, and none of them is guaranteed to be enough.

None of that is the whole story. Structure decides how far this urgency is permitted to grow, and some structures resist it at every turn. First, though, watch what happens when the same urgency meets a physical limit.

CHAPTER TWELVE

Simmering, Then Boiling

A fee does not switch on at one moment and stay off before it. It builds, the way heat does

The last chapter set out why anyone pays a fee at all, none of it requiring a crowded network. This chapter puts crowding back. Urgency does not operate in a vacuum, and once enough of it lands together, something starts happening that no individual motive accounts for.

Every Fee Deters. Some Deter Absolutely.

Every fee deters somebody. Even a trivial one prices out anyone whose transaction is worth less than the fee. The question is never whether a fee deters but how much activity it excludes, and that share climbs steeply once congestion arrives.

Consider how water behaves in a sealed vessel. It simmers long before it boils, small bubbles forming and collapsing, modest activity. Seal the vessel and rising steam pressure forces the water to a higher temperature before boiling begins at all. Same liquid, more heat required, because the space around it changed. Fee markets behave this way. Below congestion a fee exists but stays modest, the equivalent of a simmer. Past congestion the same fee must climb further to buy the same outcome, the sealed vessel demanding more heat.

> *A single chain either has room or it doesn't. A network built from many parallel blocks has room, then less room, then less again, long before it runs out entirely.*

One Container Versus Many

Here a single-leader chain and a parallel one diverge, and here their fee markets start behaving differently. A single chain has one vessel to fill. Congested or not, a binary switch. A network of many parallel blocks fills by degrees, one block reaching capacity while others still hold room, so pressure accumulates in stages long before everything is full.

Nor is the threshold fixed. As a parallel system scales and adds simultaneous blocks, more of them collide and interfere, lowering the point where fee pressure first shows even while total capacity keeps climbing. A network shaped this way simmers longer, and more visibly, than a chain that can only be full or empty.

Who Gets Priced Out First

Congestion does not raise a fee evenly across everyone using a network. It sorts them, and the sorting runs in a fixed order.

Recall what the four urgencies were worth. The ones bounded by an opportunity can pay whatever the opportunity justifies, and a genuine edge justifies a great deal. Plain impatience cannot. Somebody who would simply rather not wait has no prize to measure the fee against, so they are the first to decide the wait is preferable after all. Then the small transactions go, whatever their motive, because a fee that is trivial against a large transfer is absurd against a small one.

What remains under real congestion is a market made of edges. Whoever is racing something keeps paying, because losing costs more than the fee. Everyone else has left. The network still processes transactions and still collects fees, but it has quietly stopped serving most of the reasons people came to it.

> *A congested network does not lose its fee market. It loses everybody who was not in a hurry.*

Which is why the simmer matters more than the boil. Below congestion, all four reasons pay something and the network serves all of them. Past it,

the base of ordinary use burns off first and what remains is narrower and more valuable per transaction. A network living permanently in that state has a fee market and very little else.

The Missing Piece

So congestion bites, and it bites differently depending on whether the system underneath holds one vessel or many. Congestion is still not the only reason anyone pays a fee, and probably not the most common.

What remains is the question of why some networks ever develop a large fee market while others never do, and that answer was settled by structure long before any fee was paid.

CHAPTER THIRTEEN

A Structure That Fights Itself

Some networks are built to let a fee market grow. Others are built, without meaning to, to strangle their own

The last two chapters covered how a fee market behaves under load and why anyone pays into one. Neither explains why such a market grows large in some systems and stays small in others. That difference is structural, settled long before any fee changes hands.

Widening the Chain Kills the Thing It Was Meant to Save

A single-leader chain faces an obstacle a parallel network escapes. Raising throughput does not merely add capacity, it threatens the congestion a fee market feeds on. A chain that never fills never charges for priority, because no priority exists to sell. Widening it to prevent congestion dismantles the mechanism meant to replace the security issuance can no longer fund.

The bind sits on the base chain, and once the choice is to widen that layer directly, no policy escapes it. A single chain picks between comfortable fees now and a functioning fee market later, because the two pull opposite ways. Building capacity somewhere else, a separate system settling back onto the same base periodically, is a different structure and escapes the trade, because it never relieves the base layer's congestion at all.

> *A single container can be widened to relieve pressure, or left narrow to build it. It cannot do both.*

A Structure With No Such Trade

A parallel network of simultaneous blocks avoids the trade. Adding capacity there does not remove what fees buy, because urgency between competing users survives however much room exists. Raising throughput in that design grows the conditions a fee market needs instead of erasing them.

Which is why two networks chasing identical goals, more capacity, more adoption, more usage, end up with fee markets moving opposite directions. Growth erodes one system's future security budget. Growth builds the other's.

An Honest Complication

Fee growth is not purely good, and the cost deserves naming beside the benefit. A miner earning more per block, issuance plus a rising fee, holds more coins to sell against the same continuous operating costs described earlier. Short term, that adds selling pressure even while it lowers joules per coin, a compression competing hashrate then erodes, and never a change in the marginal machine's efficiency.

Both hold simultaneously. Lower production cost is durable and structural. Added selling pressure is immediate. Neither cancels the other, and any fair account of fee growth carries both.

The Handover

Everything in this part has been leading somewhere specific, and it is worth arriving there plainly. Two streams pay for security. One shrinks on a schedule written into the protocol and answerable to nobody. The other

grows or does not, depending on whether people find enough reason to pay for going first.

There is no arrangement where both are large at once for long. Issuance is largest when a network is young and least used, which is exactly when fees are smallest. Fees can only become large once a network carries enough activity to make priority worth buying, which takes years, by which point issuance has already faded. The whole history of a proof-of-work money is one stream handing off to the other, and the handover has to complete before the first stream reaches nothing.

> *The subsidy is not a permanent feature. It is a bridge, and bridges are built to be crossed exactly once.*

Which reframes the structural bind rather than repeating it. A chain that keeps its fees comfortable is not making a pricing decision. It is spending part of the bridge. Every cycle passed without building a fee market is a cycle of issuance consumed without replacing it, and issuance does not come back. A parallel network is not exempt from the handover either. It is only exempt from having to choke itself to make one happen.

Whether any network completes the crossing is not something this book can settle, and nobody should pretend otherwise. It has never been done. Every proof-of-work money alive today is still walking on subsidy, with the fee side of its budget somewhere between negligible and modest. The mechanism is sound and the reasoning is honest. The event has not happened.

Closing In

So a fee market grows on competitive urgency requiring no congestion, behaves differently depending on whether a network holds one thing at a time or many, and expands most easily where the structure is not fighting its future. In some systems it stays permanently suppressed by the very design meant to keep things simple.

Part Three closes with what all three of these chapters add up to: a name for the whole mechanism, and an honest account of what still isn't settled.

CLOSING

What Holds, and What Doesn't Yet

The name, tested, traced to its source, and closed with an account of its limits

CHAPTER FOURTEEN

What This Is Called, and Why

A name stated at the start is a promise. A name earned at the end is a conclusion

This book opened under a name it had not yet earned and said so at the time. Fourteen chapters on, the moment has come to return to that name and ask whether everything built since still supports it, or whether something broke quietly along the way.

The Local Half

A Carnot cycle returns to its starting state, phase for phase. Chapter seven tested that against the four-phase cycle this book had walked twice by then, hot machines meeting a new price, the rush behind it, the stillness at the bottom, the climb back out. The claim held. The local cycle lands close to where it began.

Nothing built since disturbed it. Part Two gave the cycle units, joules per machine, joules per coin, capex as prepaid opex, without altering its shape. Part Three added a second revenue stream, and every test landed identically: a fee-driven profitability gap behaves like a price-driven one, competed away by the same local mechanism on the same local clock. The fee lever moves fast and reverses. It never reached the slow half.

The Global Half

A ratchet moves one way. The joule floor, defined back in chapter three as the energy a single machine spends per unit of work, only steps down, and only when a better machine, counting efficiency and power price together, takes over as marginal producer. Competition can bid a machine's price up and down forever and never touch it, because price is what a machine costs to buy and this is what it costs to run.

This claim carries the title's second half and therefore needs the hardest stress-testing. A rising fee was the strongest candidate across three parts for something capable of moving the global floor the way a new machine does. It cannot. It changes total revenue rather than physical efficiency, and revenue changes are precisely what the local cycle absorbs and reverses. The floor stayed put.

> *Every test run against this book's own title tried to break one half or the other. Neither half broke.*

Why the Split Was the Right Call

One name for the whole mechanism would have been simpler, and wrong. A single label covering both halves would have to pick cycle or ratchet, and the honest answer is that this system is both, at two scales, for two reasons.

Locally the same conditions recur. Machines get bid up, coins get sold, both markets fall still, and it starts again, because no single turn permanently alters what the next turn looks like. Globally something does change permanently, once, each time a better machine arrives, and no mechanism anywhere in this book can undo it.

One Chapter Left

So the name holds, tested against everything built since it was first called unearned. Carnot local, because the fast half returns to where it started. Brownian global, because the slow half never does.

Two chapters remain. One traces both names back to the thought experiments they came from, neither of which was ever built. The other extends to the unsettled questions the honesty this chapter just gave the settled ones.

CHAPTER FIFTEEN

The Machines That Were Never Built

A name can be earned without showing where it came from. This chapter shows where

Chapter fourteen tested the title against everything built before it and confirmed the name holds. What it never did was say where the two names come from, or point at which part of the network plays which part. Both come from thought experiments, neither of which was ever meant to be built, and that turns out to matter.

The Engine Nobody Can Build

A Carnot engine cannot be built. Sadi Carnot described it in the eighteen-twenties as an idealisation, an engine with no friction, no leakage, nothing wasted anywhere, precisely so he could work out the most any heat engine could possibly achieve. Every real engine falls short of it. That was the point. It is a ceiling, not a blueprint.

On paper it has four parts and runs four stages. A hot reservoir and a cold reservoir sit at different temperatures. Between them, a working substance, usually a gas, drives a piston. The gas expands against the hot reservoir, absorbing heat and doing work. It expands further, cut off from that reservoir, cooling as it goes. It compresses against the cold reservoir, shedding heat. It compresses again, isolated from both, until it arrives exactly where it began.

That final detail is the whole point, and the whole reason this book borrowed the name. A Carnot cycle returns to its starting state precisely, every time. One full lap changes nothing about the next.

> *Carnot did not describe an engine anyone could build. He described the one nobody could beat.*

Where Each Part Lives in This Book

The hot reservoir is human demand itself, the urgency to transact and the wish to hold something that keeps its value, arriving from outside and indifferent to what anything costs to make. The cold reservoir is the cost of production, the joules a coin cannot be minted for less than. Everything the engine does happens between those two.

The working substance between them is hashrate, swelling as heat enters and shrinking as it leaves. The work extracted is not the coin itself but what the coin certifies: security, finality, a record of what happened and when, paid for in energy nobody can fake.

That mapping settles something the book has circled for chapters. A Carnot engine's efficiency depends on the distance between its two reservoirs and on nothing else. Widen the gap and more work comes out. Close it and the engine stops. The profitability gap is that distance. Which is why a bottom is not a mood or a failure of nerve. It is an engine at the end of its stroke, demand having fallen to meet the cost of production, with no temperature difference left to work across.

The idealisation earns its keep a second way, and this one is easy to miss. Carnot's engine is a ceiling nothing reaches, and what separates any real engine from it is friction, heat going somewhere that does no work. The same subtraction applies here. Effort spent on blocks that lose the race is friction. Rewards thinning as they route through intermediaries is friction. Every leak named at the close of Part One is the distance between a network and the bound it is working against.

Which gives soundness a cleaner definition than a supply schedule ever could. A sound network is one running close to the ceiling. A less sound

one has the same parts arranged the same way and loses more of the work on the way out. Neither is a different machine. One is simply further from the limit than the other.

The Ratchet That Cannot Work

The second device needs more care, because the version most people know is the one that fails. Richard Feynman described a vane in one bath, jittering as molecules strike it from every angle, sharing an axle with a toothed wheel held by a pawl in another. It looks like it should turn one way and lock, converting random motion into free directed work.

It does not, and Feynman built it to show why. The pawl sits in the same noise as everything else. Without energy spent continuously keeping it rigid, it lifts as often as it holds, and the wheel drifts nowhere. The thought experiment exists to prove that directed motion from pure randomness is impossible. It is a demonstration of failure.

What runs in a proof-of-work network is not that device. It is the one that works, and the difference is the whole reason this book is not called Carnot Local, Feynman Global. A Brownian ratchet is the class of real systems that do convert undirected fluctuation into accumulating progress, and they manage it for an unglamorous reason: something pays, continuously, to hold the asymmetry rigid. The pawl is not free. It never was.

> *Feynman built a ratchet to prove it cannot work for free. This one works because it is not free.*

Name what does the paying here and the mechanism stops being a metaphor. Hashrate does not retreat when price falls, because retreating means abandoning infrastructure already bought and paid for. Coins do not leave storage at the bottom, because moving them has no upside in that moment. Neither of those is a choice anybody makes collectively. Both are costs already sunk, holding the wheel against slipping back, and both keep holding only while something keeps funding them.

Where Each Part Lives Here

The vane, jittering with no net direction, is the local cycle. Price and hashrate run hot and cold, expand and compress, and land close to where they started each lap, the reversible-looking behaviour the naming chapter already tested.

The teeth and pawl are the marginal-machine mechanism. A newer, better machine can always displace an older one as marginal producer. The reverse, an obsolete machine reclaiming the position after being displaced, is mechanically impossible. That is the asymmetry making one direction cheaper than the other.

The two temperatures are the subtle detail separating a working mechanism from one that jitters in place. One bath is the market, fast and noisy, moving in minutes. The other is the manufacture of a better machine, chip design and fabrication moving on a slow, deliberate schedule. That mismatch in tempo, one side fast and random, the other slow and deliberate, is what prevents backward slip. Were the market and the fabs somehow to move at identical pace, the floor would jitter rather than ratchet.

Feynman's two baths were independent. These are not, and the difference sets a limit on how long the ratchet keeps clicking. Nobody designs and fabricates a better mining machine on a schedule. They do it when the return justifies the cost of trying. Let the gap stay closed long enough and the next generation goes unfunded, not because physics forbids it but because the numbers do not support it. Two boundaries stand in the way, and the economic one arrives first by a wide margin. Well before lithography runs out of room, the incentive does. When that happens the wheel stops advancing. It does not turn back, so nothing already gained is lost, but it holds where it is until a market hot enough to fund the next attempt comes along.

What Comes Next

So the local cycle is a Carnot engine, running between human demand and the cost of production, extracting work from the distance between

them and returning to its start every time that distance closes. And the global floor is a Brownian ratchet, holding what the cycle gained, not because asymmetry is free but because hashrate already built and coins already stored keep paying to hold it.

One chapter remains, and it owes the unsettled questions the honesty this one just gave the settled ones.

CHAPTER SIXTEEN

What's Still Open

Not everything here earned its place by the same route. Some was tested against events. Some has not happened yet

A book built this way owes the reader a clear line between what has been checked and what has only been reasoned through. Most of what came before belongs on the first side. A few things belong on the second, and they should be named rather than left to blend in with everything confirmed.

The Fee Mechanism Is Sound. It Has Not Been Sustained.

Part Three's central claim, that a fee lowers joules per coin locally and gets partly competed away as hashrate arrives, follows from mechanisms tested elsewhere in the book. The joule floor, one machine's efficiency, is never at stake in any of it. The reasoning holds. What has not arrived, at least not for any sustained stretch, is a fee spike large enough to test the claim at scale. Every network drawn on here has kept fees small against issuance for its entire history. The mechanism is sound. It also remains, honestly, mostly theoretical.

> *A sound mechanism and an observed one are not the same claim. This book has offered the first. It cannot yet offer the second.*

How Fees Redistribute Is Still an Open Question

This book showed fees lowering joules per coin and competing away over time, as any profitability gap does. It never worked out the deeper question of how sustained fee revenue should be distributed once large enough to matter, whether some share should smooth across time instead of paying out block by block, and what that would do to income stability for miners. An open design question, not a settled one, and the book leaves it where it found it.

A Structural Claim, Not Yet a Historical One

One boundary on the central claim deserves stating outright. The floor steps down only while somebody is willing to pay for the next machine to exist. That willingness is not guaranteed and not scheduled. It depends on a return that a long, flat market can erase entirely, and when it does, the ratchet holds rather than advances. Nothing already gained comes back, so the claim survives, but it is a claim about direction and not about pace. Whether the physical ceiling or the economic one binds harder over the coming decades is a live question this book does not answer.

Chapter thirteen argued that a single-leader chain faces a bind between low fees now and a working fee market later, while a parallel network escapes it. The reasoning survived direct scrutiny. Whether adoption ever grows fast enough to clear that bar is a separate, live question reasoning alone cannot settle. The bar exists. Nothing here proves it unclearable.

Why This Matters More Than It Might Seem To

None of this weakens what came before. A mechanism reasoned correctly from tested pieces has value before the event it describes occurs. The alternative, waiting until every claim has been observed at scale before writing any of it down, means writing only about things that already finished happening.

What matters is refusing to blur the difference. Anyone finishing this book should know which claims rest on events that occurred and which rest on reasoning events have not yet touched. Both have value. Only one deserves to be called settled.

Closing

This book opened at genesis, before price or a stable cost existed, and closed by testing its name against everything built between. The name held. The mechanism it names, fast and reversible up close, slow and one-way from a distance, is the whole of what it set out to show.

What remains unsettled is named plainly, not as a weakness, but as the honest edge of what has been checked.