

Capitalists Are Energy Vampires

The mower cuts the grass. The fuel supplies the power. A person directs the work. A share certificate receives the profit. Why?

A mower does not know who owns it. It turns fuel or electricity into a spinning blade whether it belongs to a worker, an investor, a cooperative or a council. Change the name on the share certificate and no blade turns faster. Yet the name on that certificate can decide who receives the money left after the bills and wages are paid.

That small puzzle opens onto the central claim of capitalism: capital produces a return, so the owner of capital naturally receives it.

The sentence sounds simple because it folds three different questions into one:

- 1. Production:** what physically makes the product or service possible?
- 2. Pricing:** how are machinery, finance, labour and risk valued?
- 3. Ownership:** why does a particular person have the right to the money left over?

Economics can connect these questions, but it cannot treat them as the same question. A machine may help produce without its owner doing the producing. Finance may enable a project without dictating the only fair contract. A market price may explain what a legal claim sells for without proving that the claim is deserved.

The classic defence associated with John Bates Clark says that each factor of production receives what it creates. Labour receives wages because labour adds output. Capital receives a return because capital adds output. Property then appears to do nothing more than deliver each contribution to its author. Capitalism becomes not one possible set of rules, but a natural law of distribution.

The Cambridge Capital Controversy breaks that chain at its economic centre. The controversy - named for economists working in Cambridge, England, and Cambridge, Massachusetts - asked an awkwardly basic question: before "capital" can have a measurable marginal product, what is the quantity being measured?

A mower, a blast furnace, a server farm and a half-built ship are not different amounts of one physical substance. They can be added in money, but their money values depend partly on wages, prices and the rate of return. The theory then tries to use that total value of capital to explain the very return that helped determine the total. The measuring stick bends with the thing it is supposed to measure.

Reswitching makes the problem deeper. As the rate of return changes, a business can choose one production method, switch to another, and then switch back to the first. There is no universal ladder running neatly from "less capital" to "more capital." The familiar story - more capital means a lower return and a more capital-intensive technique - is not a law.

This does **not** mean that tools are useless, that businesses cannot be valued, or that every model in modern economics collapses. It means something narrower and more important: economics cannot generally start with one independently measured lump called capital and derive the owners' normal return from its physical marginal product.

Other theories avoid that particular error. Austrian economics explains pure interest through preference for sooner rather than later, and entrepreneurial profit through judgment under uncertainty. Its separate property theory explains who receives the claim. Marxian economics

says that living labour creates new value while machinery passes on old value, even though Marx fully recognises the machine's enormous physical effect. Both approaches expose useful distinctions. Neither finds a share certificate inside the production process.

Once the economic alibi has been tested, we can turn to the physical world. Production rearranges matter by using **exergy**: the useful-work potential carried by fuel, electricity, food and other physical differences. Industrial capitalism has relied especially heavily on fossil fuels. Workers, knowledge, organisations and particular machines direct that work potential. Legal ownership does not supply energy, but it powerfully controls access and routes the income.

This is not an attempt to turn joules into pounds. Thermodynamics cannot set a price, measure moral desert or choose an owner. Its role is simpler: it shows what performs the physical work and what does not. The machine channels exergy. The title channels money.

The moral claim must therefore be stated openly. The rule used here pays for worn-out assets, real work, finance, delay, difficulty of resale, useful commitments and the investor's exposure to loss, valued from the information available when the bargain was made. It then rejects an additional open-ended claim based only on the power to exclude. Under this **anti-rentier** principle, finance receives a rule fixed in advance and capable of ending: perhaps redemption on a stated date or formula, a terminating share of revenue, or an annuity with a finite value when issued. This benchmark is a moral choice; it is not simply whatever contract the parties happened to sign. Readers who accept a different theory of property may reject it. No equation can settle the disagreement for them.

The argument proceeds in six moves:

1. State the classic claim that capital creates and therefore earns its return.
2. Use Cambridge to show why that claim fails as a general explanation.
3. Test the modern general-equilibrium, Austrian and Marxian alternatives on their own terms.
4. Use thermodynamics to describe the actual production process, including nature's fossil contribution.
5. Separate genuine compensation for work, finance and risk from income caused by control of scarce access.
6. Show that the final assignment of profit comes from property law and a moral choice, not a natural law of economics.

Billy's landscaping business

Suppose Billy puts GBP 5,000 into a limited company but needs another GBP 5,000 to start a landscaping business. A bank refuses the loan. An investor supplies the money in exchange for ordinary shares carrying 51 percent of the votes and distributions.

Legally, the investor owns shares - not 51 percent of each mower, van or fuel can. Billy receives a wage for his work. If the company lawfully distributes what remains, the shares divide it 49:51.

Assume one billed hour produces the following accounts:

Item	Amount
Customer payment	GBP 100.00
Fuel and other variable inputs	-GBP 10.00
Fixed costs and genuine depreciation allowance	-GBP 5.00
Billy's wage	-GBP 50.00
Residual profit available for distribution, corporation tax set to zero	GBP 35.00

Item	Amount
Billy's 49% dividend	GBP 17.15
Investor's 51% dividend	GBP 17.85

Accounting cautions. To keep the arithmetic visible, corporation tax is set to zero and the company is assumed to meet every legal test for distributing the full GBP 35. The GBP 5 fixed-cost line is also assumed to cover maintenance, replacement, insurance, administration and non-billable time. If it does not, the profit is overstated. Real accounts would need to include tax, retained earnings and every omitted cost.

At 1,800 billed hours a year, the company receives GBP 180,000. On the stated figures it can distribute GBP 63,000. Billy receives GBP 30,870 in dividends as well as GBP 90,000 in wages. The investor receives GBP 32,130 - 642.6 percent of the original GBP 5,000 in the first year, before personal tax and any change in the share price.

Nothing in that arithmetic is illegal or mysterious. The shares carry 51 percent of a lawful distribution, so the company pays it. But the calculation tells us what the investor's title **receives**. It does not tell us what that title **produces**.

The labels do not settle the matter. Calling GBP 50 Billy's "market wage" does not prove that GBP 50 captures his entire contribution. Calling the remaining GBP 35 "profit" tells us where the accountant drew a line; it does not measure what each input caused or establish who deserves the remainder.

Suppose the GBP 63,000 could be earned year after year, the company had no net debt, and a buyer valued it at five times annual earnings. The whole company would then be worth about GBP 315,000, and the investor's 51 percent stake about GBP 160,650 before adjustments for control or difficulty of sale. That figure is the market value of an expected income claim. It is not evidence that the investor personally produces GBP 32,130 each year.

Keep three numbers separate. The 642.6 percent is a return measured after the fact against the GBP 5,000 outlay. The GBP 160,650 is a possible price for the shares. The mower has its own purchase and replacement cost. None is the theoretical quantity κ challenged in the Cambridge controversy.

Cambridge uses r for a theoretical normal profit or interest rate, not Billy's realised dividend yield. Nor does standard marginal-product theory say that every company dividend equals capital's marginal product. Under its cleanest assumptions, factor payments use up the whole output and leave no pure economic profit. Billy's numbers show how a contract divides a residual; they are not a numerical proof of Cambridge.

The investor nevertheless contributed something real: GBP 5,000 at risk when Billy could not obtain the bank loan. Waiting, genuine loss exposure, due diligence, advice and entrepreneurship may all deserve payment. If Billy also lacks realistic alternatives, however, the investor may be paid partly for controlling scarce finance. Economists call that extra bargaining return a **scarcity rent**. Nothing in the accounts separates fair compensation from rent or proves that either naturally equals 51 percent for as long as the company survives. The contract chooses that number before the first lawn is cut.

This is the distinction the textbook story blurs. There are at least three different things called "capital":

- 1. Capital goods:** mowers, trucks, computers, buildings and other produced means of production.
- 2. Financial capital:** money advanced to acquire assets and fund operations.
- 3. Capital ownership:** an enforceable title specifying claims on future income and, in some forms, control.

The mower helps Billy cut grass. The GBP 5,000 enables the mower to be bought. The company's legal arrangements determine who may receive distributions from the residual. These are related, but they are not the same causal act.

Capital goods can be physically productive without the title itself being a physical input. Property arrangements may affect incentives and allocation, but that is a separate institutional mechanism.

Capitalism's cleanest alibi

A classic aggregate marginal-product defence does not say that the investor's banknotes secretly cut the grass. It says that the banknotes put capital goods at Billy's disposal; the goods add to output; competition imputes the added product to capital; and the owner of capital receives the corresponding return.

In its elementary form the argument begins with a production function:

$$Y = F(K, L)$$

Here Y is output, L is labour and K is capital. In the textbook's cleanest version, the output price is set to one, the firm takes prices as given, and its choices change smoothly. Calculus then gives:

$$w = \text{partial } F / \text{partial } L$$

$$\rho = \text{partial } F / \text{partial } K$$

The notation $\text{partial } F / \text{partial } L$ asks how much output changes when labour rises a little while capital stays fixed. The equation says the wage w equals the extra output from a little more labour. The rental ρ equals the extra output from a little more capital **service**. It is not yet an equity dividend or an interest rate.

If doubling both inputs exactly doubles output - **constant returns to scale** - Euler's theorem gives:

$$Y = wL + \rho K$$

In plain English, the model divides the whole output between labour and capital services. No pure economic profit remains. In the most stripped-down one-good version, $\rho = r + \delta$: the machine's gross rental covers the net return r plus wear and tear δ . In a real asset market, taxes, the machine's price and expected capital gains also matter.

Notice what the equations contain: labour and a capital **service**. They contain no shareholder. The owner enters when property law directs the payment for that service to whoever holds the title. The calculus can price an input under strict assumptions. It cannot write a deed or prove that the deed is deserved.

John Bates Clark stated the promise unusually plainly. His *Distribution of Wealth* set out to show that distribution is governed by a "natural law" under which every productive agent receives the wealth it creates. In that picture, interest is not a deduction from somebody else's product. It is capital's own product reaching its rightful recipient. This is capitalism's cleanest alibi: no class takes from another; each receives what its factor made.

Modern economics is more varied and more cautious. Accounting profit, interest, rent, dividends and capital gains are different things. They may contain payment for risk, innovation, management or market power. The problem begins when a defence of ownership slides through three separate claims:

1. Particular tools and machines can increase output.
2. "Capital" has a separately measurable marginal product that determines its return.
3. The owner of capital is morally entitled to that return.

The first claim is true. Cambridge defeats the second only as a universal claim about capital taken as one whole; it does not refute every price condition for a particular machine. The third is a rule of property, not a result of calculus. Cambridge removes one famous technological defence of capital income, not every possible practical or moral defence.

Call the disputed payment a **title-only residual**, or **profit received simply because of ownership**. It is what remains after the business has replaced worn-out assets and paid for work, management, the money advanced, waiting, difficulty of resale and genuine risk of loss. This is not the same as ordinary accounting profit. Neither Cambridge nor thermodynamics can tell us what amount would be fair; that requires an openly stated moral rule. The term does not include repayment of the original finance, a manager's wage, maintenance, insurance or compensation for real risk.

The quantity that has to exist before it can explain anything

The elementary neoclassical parable writes production as:

$$Q = F(K, L)$$

Output Q is produced with labour L and capital K . Workers differ too, of course, but a basic model can at least count hours or adjusted labour units. What unit counts a blast furnace, a laptop and a delivery van as pieces of the same thing?

A landscaping firm owns mowers, strimmers, a van, fuel cans, computers and perhaps a building. An economy contains blast furnaces, semiconductor plants, railway lines, scalpels, software and half-built ships. We can list these things separately. We cannot add them into one meaningful physical amount. Ten tonnes of steel is not simply "more capital" than one chip-making machine.

Money supplies a common unit. If the economy has quantities q_i of different capital goods at prices p_i , their total money value is:

$$K = \sum_i p_i q_i$$

This is sound accounting. It lets a mower and a van appear on the same balance sheet. The trouble begins only when the money total is treated as a physical cause of the rate of return.

The prices p_i are not permanently stamped onto the machines. They depend partly on wages, the return required on money tied up, and when costs and receipts occur. A machine that costs money now but pays off years later becomes less valuable when the required return rises. Because industries use labour and equipment in different amounts and at different times, a change in the division between wages and profits changes their relative prices unevenly.

Different theories use different rates here. Sraffian models use r for a common profit rate on money advanced. Neoclassical models link an interest or asset-return rate to the rental price of a machine through a separate user-cost equation. Neither rate is automatically the same as Billy's accounting profit or dividend yield.

Choose a **unit of account** - called a numeraire - and hold the production method fixed. The wage w and profit rate r then sit on a trade-off curve rather than moving independently. For a fixed collection of machines, the technical shorthand is:

$$K_v(r) = \sum_i p_i(r, w(r)) q_i$$

The notation says that the total value K_v changes with r , because the prices used to add the machines change with r and with the wage linked to it. If the business also changes its production method, even the quantities q_i may change.

Yet the marginal-product story wants to run the explanation backwards: first measure K , then use the amount of K to explain r . Capital is said to earn less when it is abundant and more when it is

scarce. The supposed cause has already been measured using prices shaped partly by the supposed result.

That is the Cambridge measurement problem. There is nothing wrong with solving prices and distribution together; economists do it all the time. There is also nothing wrong with valuing a business from its expected cash flows. The mistake is to present the resulting money value as an independent physical quantity that caused the return used to value it.

Sraffa's price system makes the two-way dependence visible. In a stripped-down model, A records the produced inputs needed for each good, p their prices, e_{ll} the labour required, w the wage and r the profit rate. Suppose wages are paid at the end of the period. Then:

$$p = (1 + r) p A + w * e_{ll}$$

In plain English, the selling prices must cover the produced inputs, enlarged by the profit rate, plus the wage bill. Once the production methods and a unit of account are fixed, choosing the wage limits the possible profit rate, and choosing the profit rate limits the wage. The physical machinery alone does not announce which point the economy must occupy. Change the distribution and relative prices usually change too.

This is a model, not the last word on how wages and returns are set. Other theories add consumer preferences, existing wealth, demand, bargaining, government policy or market power. The Cambridge point survives: distribution cannot be derived from a pre-existing physical lump called capital whose marginal product dictates its owner's share.

As Avi Cohen and G. C. Harcourt explain in their [retrospective on the controversy](#), the simple model generated three influential parables:

1. The return on capital is determined by capital's diminishing marginal productivity.
2. More capital per worker implies a lower return and the adoption of more capital-intensive methods.
3. Wages and profits are explained by the relative scarcity and marginal products of labour and capital.

Under the model's usual assumptions, those propositions work cleanly in a one-commodity world where the same good can be both output and capital. In a world of heterogeneous capital goods, they do not survive as general theorems.

Reswitching: when the same method wins twice

The deepest result is not merely that capital is hard to measure. It is that production methods cannot always be ranked from "less capital-intensive" to "more capital-intensive" independently of the rate of return.

Paul Samuelson demonstrated this with a deliberately simple champagne example in his 1966 paper "[A Summing Up](#)". Two techniques produce the same output but use labour at different dates.

- Technique A uses 7 units of labour two periods before the champagne is ready.
- Technique B uses 2 units of labour three periods before completion and another 6 units one period before completion.

If w is the wage and r the rate of return, their costs at the date of sale are:

$$C_A = 7w(1 + r)^2$$

$$C_B = 2w(1 + r)^3 + 6w(1 + r)$$

The wage cancels when the two costs are compared. The cheaper method changes with r :

Rate of return	Technique A	Technique B	Cheaper technique
0%	7.00w	8.00w	A
75%	21.44w	21.22w	B
120%	33.88w	34.50w	A

The switch points are 50 percent and 100 percent. Read the table from a high return to a low one. Technique A is cheapest, then B takes over, then A returns. The production method has made an economic U-turn. The same physical technique wins at both a high and a low rate, while another wins in between.

That is **reswitching**.

The percentages are deliberately dramatic so the arithmetic is easy to see. The example does not tell us how often reswitching occurs in the real world. It does not need to. One valid reversal is enough to disprove the claimed law. Production methods cannot always be placed on one permanent ladder from "less capital-intensive" to "more capital-intensive."

How often these reversals matter empirically is a separate and disputed question. It matters for the usefulness of a particular applied model; it does not restore the model's universal causal claim.

The formal point itself was conceded. David Levhari and Samuelson explicitly withdrew an earlier result in a 1966 note titled "[The Nonswitching Theorem Is False](#)".

Capital reversing is a related surprise. At a switch, the method chosen when returns are lower can contain a lower money value of capital per worker, not a higher one. The supposed demand curve for capital need not slope neatly downwards. "Capital is dear because it is scarce, and cheap because it is abundant" is therefore not a general result when capital goods differ.

Samuelson accepted the key result: once capital goods differ, the familiar textbook rules are no longer universal. Modern general-equilibrium theory can still price particular inputs and compare goods available at different dates without using a single quantity K . Cambridge therefore did not destroy general equilibrium. It destroyed the claim that one measurable stock of capital must determine its own normal return. The remaining question is whether the newer theory explains a general return to owners - and why owners should receive it.

Claim	What the controversy establishes
Machines and tools can raise output.	Untouched. Physical capital goods are productive.
Businesses and assets can be assigned money values.	Untouched. Accounting, market and discounted-cash-flow values remain usable.
Heterogeneous capital is a single physical quantity independent of prices and distribution.	Fails in general. Aggregation requires valuation, and valuation depends on distribution and the return.
More aggregate capital necessarily means a lower return.	Fails in general. Reswitching and capital reversing break the monotonic relation.
The aggregate marginal product of capital provides a one-way causal explanation of the normal return to aggregate capital.	Fails as a universal story. The value aggregate is not generally independent of the return it is invoked to explain.
A positive interest rate can be explained as a premium on present over future goods without aggregate K .	Not addressed. Austrian time-preference theory avoids the aggregate marginal-product claim; it does not by itself identify the owner of present goods or justify an indefinite equity claim.
Every return to ownership is therefore theft.	Not established. That requires a further institutional and moral argument.

What Cambridge has proved - and what remains

The controversy's achievement is negative but decisive. It blocks the move from a stylised production function to a natural law of distribution by the aggregate marginal-product route.

There is nothing wrong with equations that determine wages, prices and returns together. The problem begins when capital's money value is later presented as an **independent physical cause** of the return, even though that return helped determine the value. Cambridge showed that the measuring rod already contains part of the answer it is supposed to discover.

So the verdict is exact:

- machines remain physically real and useful;
- finance may make projects possible and bear genuine losses;
- accounting and market valuation remain possible for their own purposes;
- but a distribution-independent aggregate K cannot generally determine a unique class contribution and naturalise the owners' return by the aggregate marginal-product route.

Even equality between a rental price and a correctly computed disaggregated marginal product would be a positive equilibrium result, not a deed of title. "This asset contributes to output" and "therefore its present legal owner deserves an open-ended claim on output" are different propositions. Cambridge defeats the universal aggregate bridge; it does not yet tell us what production positively is.

Modern disaggregated general equilibrium offers a mathematically serious alternative: it can formulate equilibrium prices for particular commodities without constructing aggregate K . Its success also reveals exactly which claims have been abandoned.

The sophisticated escape hatch: stop pretending capital is one thing

At this point a modern economist can fairly object: why squeeze mowers, blast furnaces and chip factories into one quantity at all? Count each particular good separately.

That is what **disaggregated general equilibrium** does. A mower today, a mower next year and a mower available only if a particular event occurs can be treated as different goods. The model describes what households want and own, what firms can produce, and who owns the firms. It then looks for a set of present and future prices at which everyone's plans fit together. Gerard Debreu's [Theory of Value](#) distinguishes goods by their physical features, date, location and possible future state.

This successfully avoids the aggregation error. It removes the disputed object K rather than repairing it. The model can price a particular mower service and relate the mower's price today to its future rentals. It cannot then be cited as proof that a homogeneous substance called capital creates the economy-wide profit rate. General equilibrium survives Cambridge because it does not make the claim Cambridge defeated.

What the disaggregated equations actually say

For readers who want the algebra, take a smooth model in which the firm accepts market prices and uses a positive amount of each input. Let $s_{j,t}$ be the service supplied by machine j during period t , $u_{j,t}$ its rental, $p_{y,t}$ the output price and f_t the period- t production function. Then:

$$u_{j,t} = p_{y,t} (\text{partial } f_t / \text{partial } s_{j,t})$$

For a durable machine, let $P_{j,t}$ be its price now, $u_{j,t+1}$ the next period's rental, δ_j its rate of wear and i_t the one-period interest rate. If taxes and adjustment costs are ignored, buying and renting must satisfy:

$$(1 + i_t) P_{j,t} = u_{j,t+1} + (1 - \delta_j) P_{j,t+1}$$

Read the equations this way. The first prices one extra unit of service from a **particular machine**. The second links the machine's price today to next year's rental income and resale

value after wear. If the future is uncertain, the calculation must also allow for risk. None of this requires capital to be treated as one physical substance.

Nor does it recreate such a substance. A machine's rental is not the interest rate. Its purchase price is not a physical quantity of capital. Neither number is automatically an equity dividend or the economy-wide profit share. The equations connect prices across time; they do not prove that a single normal return is the physical product of K .

The difference can be stated exactly:

Question	Aggregate marginal-product parable	Disaggregated general equilibrium	What follows
What is "capital"?	One number K , measurable before distribution.	Particular goods and services separated by kind, date, place and sometimes future event; financial claims are separate objects.	The factor whose marginal product was meant to explain a class return has been removed, not repaired.
What is priced?	$\partial F / \partial K$, linked through the cost of using an asset to a normal return.	Particular rentals or shadow prices, asset prices and price ratios across time.	A mower-service rental is not automatically interest, accounting profit or an equity residual.
What is the causal story?	More K lowers its marginal product and therefore r .	Prices, plans and quantities are jointly determined from preferences, starting resources, technology and market rules.	No universal one-way path from more K to a lower r has been recovered.
Can capital accumulate?	"Less" and "more" capital are ordered along one dimension.	Future goods can be produced and securities can be traded; the inherited physical structure is initial data.	GE need not freeze machines forever, but an equilibrium allocation is not by itself a proof of an actual adjustment or convergence process.
Where does ownership enter?	The owner's income is presented as the product of the owned factor.	Initial endowments and claims on firms enter the private-ownership economy as data.	The model can calculate consequences of a property map; marginal productivity does not derive or justify that map.

This is the serious mainstream reply. As [Cohen and Harcourt](#) explain, economists such as Bliss and Hahn kept simultaneous price-setting and marginal conditions for particular goods. They did not restore the simple inverse link between one quantity of capital and the interest rate. [Hahn](#) accepted that adding capital into one theoretical quantity was unsound, while arguing that advanced general equilibrium did not need to do it. The defence works because it makes a smaller claim.

Separating the machines does not undo reswitching. Samuelson's example already compares inputs used at specific dates. In a stationary model governed by one rate, the same method can still be cheapest at separated high and low rates. A fully flexible Arrow-Debreu model instead uses many prices for many dates, so it has no need to rank every technique on one ladder of "capital intensity." The broken claim has been dropped, not repaired.

Disaggregated general equilibrium becomes a **disguise** only when conclusions it never proved are read back into it: a local machine rental becomes "the return to capital"; a price across time becomes capital's physical product; or an allocation based on existing titles becomes proof that those titles were earned.

Money can move; machines cannot

An investor can sell shares in a steel company and buy shares in a software company within seconds. The steel mill does not turn into servers. What moves is a legal claim and the power to spend, not the installed equipment. General equilibrium is right to keep unlike productive goods separate from financial securities.

The distinction has a cost for the old story. Financial wealth cannot be slipped back into the production function as though a pound of shares were a physical input. Finance can change what is produced by changing access, timing, incentives and the plan chosen. Those are real effects

and should be modelled directly. The ease of selling a title does not turn unlike machines into one physical quantity κ .

Some short-run models treat installed equipment as fixed, so the rental of a scarce machine may be a temporary scarcity price. Broader models can include investment, new machines and changing portfolios. It would be wrong to call every machine rental a bottleneck rent or to claim that all general-equilibrium models freeze history. The narrower point survives: pricing particular inputs and future claims does not recreate a marginal-product theory of the normal return to owners as a class.

Technical interlude: does an equilibrium describe a moving economy?

Economists in Cambridge, England raised another question: does this equilibrium explain how a real economy changes through time? Classical and Sraffian economists wanted to explain the normal prices and profit rate towards which competition might push a changing economy. Arrow-Debreu theory asks something different. It begins with existing resources and ownership, imagines markets for present and future goods, and finds prices at which everyone's plans are compatible.

The model can include planned investment, but it does not by itself describe the journey from one situation to another. Expectations change, banks deny credit, investment alters productive capacity and people revise their plans. Proving that a consistent allocation exists does not prove that a real economy will move towards it.

This second criticism remains disputed. Garegnani's [assessment](#) calls the aggregate-capital case conclusive but the argument about models through time unresolved; [Fratini's survey](#) is similarly cautious. Reswitching can produce several possible equilibria or unstable adjustment in some models, but it does not prove that a disaggregated equilibrium can never exist.

The choices are nevertheless clear:

- 1. Treat every dated capital good separately.** Then the model needs no independent κ , has no aggregate partial $F / \partial \kappa$, and supplies no universal path from more κ to lower r . It may find an equilibrium and local prices, but it has abandoned the old explanation of the profit rate.
- 2. Bring back a single money fund called capital.** If that fund is then used as an independent cause of the return, its price dependence must be confronted again. Calculating savings or present values is not circular. Treating a value shaped by r as the prior cause of r is.
- 3. Use Billy's mower rental to justify the shareholder's dividend.** That confuses the service of a machine with a legal claim on the company. The equation may price use of the mower. It does not show that a share certificate cuts grass or naturally earns 51 percent of every future residual.

The shareholder enters as an assumption

The separation between production and ownership is visible inside the standard complete-market, price-taking model shown here. In other models, ownership and control may change financing and production decisions; those effects must be modelled directly. Let Y_j be everything firm j could physically do, y_j the plan it chooses and p the list of prices. The firm chooses the most profitable feasible plan:

$$p_{i,j}(p) = \max \{ p \cdot y_j : y_j \text{ in } Y_j \}$$

The mower's service appears in that production plan. The shareholder's identity does not. Ownership appears somewhere else: in a household's spending limit.

$$p \cdot x_i \leq p \cdot \omega_i + \sum_j \theta_{ij} p_{i,j}(p)$$

Here ω_i means what household i owns at the start. The coefficient θ_{ij} is its assigned share of firm j 's profit. The [Arrow-Debreu existence paper](#) puts initial holdings and claims on

firms into the model as assumptions. Technology helps determine the profit π_{ij} . It does not produce the ownership share θ_{ij} .

At an equilibrium, the ownership coefficient routes the money. If ownership changes and the model is solved again, the new wealth pattern may also change demand, prices and production. That matters, but it does not turn title into a physical input. No derivative of the production equation generates θ_{ij} , still less proves that its history was just. Where profits or scarcity rents remain, initial ownership helps decide who receives them. Ownership of the starting assets also decides who receives rentals and sale proceeds.

The welfare theorems cannot fill the gap. **Pareto efficiency** means that nobody can be made better off, given the model, without making somebody else worse off. It says nothing about how the starting rights were acquired. Different starting distributions can support different efficient equilibria. An efficient outcome under a 51 percent share does not show that the share records 51 percent of production or ought to last indefinitely. Efficiency of an arrangement is not proof of its title.

Billy's mower may have a positive rental. Scarce finance may command a price across time. Neither fact derives the investor's equity share. The company owns the mower; the shareholder owns a security carrying votes and rights to distributions. Put $\theta = 0.51$ into the model and the equations can trace where the money goes. They cannot turn that input into proof that 51 percent was technologically earned.

Two ledgers remain

There is nothing confused about attaching prices to physical goods. The model describes what transformations are possible and uses prices to coordinate plans. Confusion begins only when a machine's rental or price is redescribed as its owner's physical contribution, or when an outcome based on existing titles is presented as moral proof of those titles.

Two ledgers are still needed. The physical ledger records the mower, labour, materials, useful-work potential, maintenance and waste. The money-and-law ledger records rents, share prices, debts and the rules sending receipts to particular people. Prices connect decisions across the ledgers. They do not merge them. A legal title can strongly affect access and behaviour without becoming matter, energy or useful work.

Separating the goods is therefore a valid escape from a false aggregate equation. It is not a rescue of the old conclusion. The model can determine prices for particular goods at particular dates and under particular events. It does not resurrect capital as one productive substance, turn a mower rental into class profit, or convert an assumed ownership share into an earned entitlement.

Before leaving economics for the physical process, two alternatives must be tested on their own terms. Austrian economics abandons the claim that interest is the physical product of aggregate capital and grounds it instead in time preference, entrepreneurship and title. Marxian economics denies that machinery creates new value at all, even while acknowledging its enormous physical productivity. Each captures part of the necessary distinction. Neither completes it.

Austrian economics: perhaps the investor is paid for waiting

The Austrian school takes a cleaner route. It does not need an abstract lump of capital to manufacture a physical product. It separates machines, money, waiting, judgment and ownership.

Mises calls particular machines **capital goods**. He uses **capital** for their money value in business accounts. He expressly denies that pure, or **originary**, interest is a machine's product or a reward for abstaining from consumption. A machine's usefulness helps set its price and rental. Interest arises because people value otherwise comparable satisfaction sooner rather than later. Mises

says the need to compare dates would remain even under public ownership. His discussions of [capital](#) and [originary interest](#) make these separations explicit.

The categories must therefore be kept apart:

Component of a realised return	Austrian explanation	What the explanation establishes
Originary or pure interest	Otherwise comparable satisfaction now is valued above satisfaction later.	A difference in valuation across time, reflected in prices - not a machine's product or the identity of the recipient.
Entrepreneurial profit or loss	An entrepreneur anticipates an uncertain future better or worse than others.	A temporary gain or loss from judgment. In Mises's imaginary economy without change, it disappears.
Managerial or technical remuneration	Planning, monitoring and coordination are services performed by people.	Compensation for work, whether paid as salary or contingently.
Equipment rental	A particular asset supplies a scarce productive service.	A price for using that asset under stated conditions, not an aggregate profit rate or equity dividend.
Gross investment return	Actual receipts may mix interest, a risk premium, entrepreneurial gain, rent, taxes and a gain or loss on the asset price.	A total that must be separated into its parts before it can justify anything.

In a simple time-market illustration, a capitalist pays now for inputs whose product is expected to be sold later. If x_t is treated as a certain receipt at date t , its present value may be represented schematically as:

$$P_0 = x_t / (1 + i)^t$$

With a positive rate i , the formula says that a promised receipt x_t in the future is worth less today because the recipient must wait. It prices a claim **after** the receipt and the claim have been specified. It does not create either of them.

Rothbard describes workers and other input owners as selling services for money now while the capitalist waits for the finished product to be sold. His [time-market account](#) attributes the difference to preference for present over future goods. Real uncertainty is not captured by this simple formula: judgment can produce a profit or a loss. The central point remains that discounting can value a dated legal claim once its terms exist.

What Cambridge does to the Austrian story

Cambridge does not prove that waiting has no cost. It does not break present-value arithmetic or business accounting. Those activities do not need a price-independent physical quantity K .

Cambridge does break the universal story of **roundaboutness** associated with Boehm-Bawerk. A roundabout method takes more time or more stages before producing its result. Such methods can sometimes raise output. But if the claim is that lower interest must always select a uniquely longer or more capital-intensive method, reswitching defeats it. The same timed method can be cheapest at both high and low returns. Samuelson accepted that this destroys the simple tale associated with Boehm-Bawerk, Jevons and Wicksell. Mises himself later rejected technology as the explanation of pure interest.

A modern Austrian account survives by treating machines as unlike parts of particular business plans, not as one measurable substance. Capital becomes a money calculation, interest a comparison across time, and entrepreneurial profit a result of uncertain judgment. None is the physical marginal product of an abstract lump of capital.

This is a real contribution, not a trick. Money prices help people compare very different plans using demand, scarcity and forgone alternatives. An energy balance cannot tell Billy whether customers prefer tidy gardens to some other use of his time and mower. But calculation operates inside an existing pattern of prices, purchasing power and property. It does not turn money into

fuel, guarantee that pollution has been priced, prove that starting ownership is just or show that indefinite outside equity is the only way to make economic calculations.

The Austrian defence therefore answers a different question. Time preference can explain why otherwise comparable satisfaction later is discounted against satisfaction now. It cannot explain why a shareholder physically produces 51 percent of a landscaping residual.

The property premise doing the work

Rothbard's answer to **who gets paid** comes from his theory of property, not his theory of interest. He starts with self-ownership, just acquisition of previously unowned resources and voluntary transfer. On his premises, the investor's 51 percent share is legitimate if the GBP 5,000 was justly owned, Billy gave informed and unforced consent, nobody had a better claim, no uncompensated harm was imposed and a future residual can validly be sold. [Rothbard's discussion of justice and title](#) also insists that legality alone is not enough and that stolen property must be returned.

This is a coherent **if-then** argument, but it is a moral argument. Time preference, entrepreneurship and the mower do not prove its premises. The real questions are whether the investor's starting wealth was justly acquired, whether Billy had meaningful alternatives and whether a temporary need can validly surrender an indefinite share of future joint production.

Preference for sooner over later is widespread. Control of ready money is not. A society may compare present and future needs without paying the difference to an absentee owner. Time preference does not nominate the waiter, choose a loan rather than 51 percent equity, draft voting rights or make the claim transferable and indefinite. Property theory supplies those conclusions.

Nor does the spectacular size of Billy's first-year cash return prove the opposite. A contingent perpetuity can have a finite present value:

$$V_0 = \sum \text{from } t=1 \text{ to infinity of } E[D_t] / (1 + k)^t$$

Total dividends can eventually exceed GBP 5,000 while their uncertain value at the start was no more than GBP 5,000. The shares might also become worthless. Receiving more cash than the original investment therefore does not, by itself, prove theft. The limit is elsewhere: the equation takes the dividend rights, discount rate and legal enforcement as given. It can calculate what the 51 percent title may be worth **once that title exists**. It cannot derive 0.51, prove an equal productive contribution or validate the bargaining conditions that produced it.

The holder may say that keeping the share is continuous waiting because it could be sold. That establishes an opportunity cost once the claim exists. But the sale price is the capitalised value of the same protected future distributions. Using that price as independent moral proof of those distributions would run in a circle: the receipts justify the asset value, and forgoing the asset value is then said to justify the receipts. Discounting remains sound valuation. It is not independent moral proof of the cash flows being discounted.

Bastiat's immortal plane

Frederic Bastiat - a French liberal precursor to, rather than member of, the Austrian school - offers one of the most charmingly indestructible defences of capital income. In [his plane story](#), James lends William a woodworking plane. A year later William returns an equally serviceable plane plus an extra plank. The plane can then be lent again, each borrower restoring it and adding another plank. Eventually every material part may have been replaced, yet the extra plank keeps arriving. It is capital income in Ship-of-Theseus form: the tool changes completely; the payment survives.

On the terms stipulated, a recurring rental or interest charge is not logically incoherent. Each borrower gets temporary use and promises to restore the asset or principal. If those contracts are just and renewed freely, the fact that total payments exceed the asset's original price does not refute them.

What the story does **not** show is that the original plane, or James's original labour, remains a physical producer forever. The asset is maintained and replaced out of successive borrowers' production; what persists unchanged is the lender's legal claim. The plane is a Ship of Theseus with a direct debit. That may illustrate durable title, but it cannot derive title from material contribution.

The analogy is weaker still for Billy's equity. The company owns and replaces the mower; the shareholder owns a security carrying voting and residual rights. No borrower promises to return the investor's GBP 5,000 on a fixed date, and no dividend is guaranteed. Once operating receipts fund wages, fuel, maintenance and new equipment, the shareholder need not advance each future payroll afresh. If the share is sold, a different person receives its rights while the mower, operator, fuel and lawn remain the same. The change in payee is a legal and financial event, not a change in the production process.

An active investor may still perform valuable entrepreneurial or managerial work and should be paid for it. A passive investor still bears uncertainty in the value of the finite stake. Neither fact demonstrates that every later residual, whatever its scale and duration, corresponds to equivalent continuing work or uncapped loss exposure. That question must be settled by the finance terms and the property principle, not by calling the whole bundle "waiting."

The Austrian defence therefore contains three distinct claims:

1. Money prices aid calculation.
2. Dated claims trade at a discount.
3. Valid owners may make binding contracts over their titles.

The first says what prices help people do. The second describes how claims across time are valued. The third is a rule about ownership and obligation. None automatically produces the next. Austrian economics does not prove that capital physically creates profit. In its mature Misesian form, it says interest needs no such proof. The return reaches an owner because a property system has already assigned an enforceable claim. The physics has dropped out; title is doing the work of distribution.

Marx's machine: enormously productive, but not a creator of new value

Marx takes the argument in an unexpected direction. He rejects the idea that the capitalist receives profit because "capital" produced it. He also understands perfectly well that machines and nature can multiply what people make. Yet his theory allows living labour alone to create **new value**. The machine may transform the world; it may not enter that particular ledger as a creator.

The simplified Marxian equation is:

$$W = c_{\text{used}} + v + s$$

Here w is the total product value, and c_{used} is the value transferred from purchased materials and energy carriers, plus machine wear. Marx calls this **constant capital** because it passes existing value into the product without adding new value. A free natural force such as an unowned waterfall has no purchase value to transfer. The symbol v is the wage cost of buying labour-power. Living labour then adds $v + s$: enough value to cover the wage, plus surplus value s , which the capitalist controls.

In this simplified account, the exploitation rate is s/v . A basic annual profit rate is $r = s/(C_{\text{advanced}} + V_{\text{advanced}})$: surplus divided by all the money advanced for constant and variable capital. The full theory is more complicated because machines last for years, prices do not always match Marxian values, and competition redistributes profit between industries. The simple equation is enough for the point here.

Marx keeps three ideas separate:

- **Use-value:** what something actually does. A press prints; a digger moves earth; fuel releases useful work potential.
- **Value:** in Marx's special sense, a social quantity created by socially necessary labour.
- **Price:** the money amount, affected by competition, scarcity, redistribution and many other conditions.

So Marx does not claim that machines are useless. A whole machine enters production even though only its wear enters the value account. Machinery can multiply output, make new processes possible and cheapen the goods workers need. A business with a better machine may also enjoy an extra profit until competitors catch up. But across the economy, Marx says, machines transfer old value while living labour creates new value. [Capital, volume I, chapter 8](#) sets out that rule.

Nor does Marx forget nature. In the [Critique of the Gotha Programme](#), he objects to the claim that labour is the source of all wealth. Nature also supplies material wealth, and human labour is itself a natural force. He then makes the political point: those who own the material conditions of work can make everyone else dependent on them. Marx already has two ledgers - material wealth and capitalist value - even though he gives labour a unique place in the second.

The machine does free work

The tension is clearest in Marx's own examples. In the [Grundrisse](#), he discusses a printing press whose useful effect is far greater than the small amount it loses through wear. The press may help print many times as many sheets while giving up only a fraction of its useful life. Marx attributes the extra value to more productive labour, not directly to the press.

In [Capital, volume I, chapter 15](#), he sharpens the point. A machine creates no new value and transfers only its depreciation. Yet he also says that machines work "gratuitously," like natural forces, and that this free service grows as their productive effect rises relative to their wear. The machine is physically magnificent and economically useful. It is simply barred, by Marx's definition, from creating new value.

His [waterfall example in Capital, volume III](#) almost draws the two ledgers in red ink. A factory with exclusive access to water power can produce more cheaply than rivals using steam. Nature supplies the power. If someone owns the waterfall, ownership lets that person turn the advantage into rent. The waterfall does the physical work; monopoly routes the money. Marx still calls nature only the basis of surplus value, because his theory reserves new value for living labour.

Keen tests Marx by Marx's own rules

Steve Keen attacks this boundary from inside Marx's theory - an **immanent critique**, meaning a test that uses the theory's own rules.

Marx explains surplus by treating labour-power as an unusual commodity. Its price is tied to what workers need in order to live and reproduce their capacity to work. Its use to the capitalist is the labour they actually perform. Because the second can exceed the first, the capitalist receives surplus labour and surplus value.

Keen asks why a machine is treated differently. It too has a purchase price and a productive use. Marx admits that its useful effect can greatly exceed its depreciation. If the gap between cost and productive use explains surplus in the case of labour-power, why is the same form of gap ruled out for machinery? [Keen's 1993 paper](#) argues that a consistent use of Marx's distinction would make labour one source of surplus among several.

The Marxian reply is serious. Physical output and Marxian value are not the same thing. Sheets, kilograms and joules cannot be subtracted from pounds. A better machine can increase the

number of goods while reducing the labour - and therefore the Marxian value - contained in each one. That is how mechanisation makes goods cheaper.

Within Marx's system, **labour-power is special** because its use is living labour, and living labour is what the theory defines as creating new value. A machine contains past labour. It helps current labour and passes on its existing value as it wears out. On this reading, Keen gets his conclusion only by treating physical usefulness as value creation - the very point under dispute.

That reply protects Marx's theory, but it does so at a price. Unless there is an independent reason why living labour alone creates new value, the argument can become true by definition: labour alone creates value because value is the category that labour alone creates. Keen has found a real seam, even if he has not proved that joules create pounds.

Marx's related claim about a falling profit rate also needs care. A rise in constant capital relative to labour puts downward pressure on $s/(C_{\text{advanced}} + V_{\text{advanced}})$ only if other things stay fixed. Marx calls it a tendency and lists **forces working against it**. A falling rate can coexist with a larger total profit. Nor does one profitable, machine-heavy company refute the theory: in Marx's **prices-of-production account**, competition redistributes surplus between industries.

What the dispute cannot decide

Thermodynamics cannot settle Marx's special meaning of **value**. An energy balance cannot prove that a joule creates a pound, and a machine's usefulness does not reveal a unique share of revenue. On that point, Marx's defenders are right.

But thermodynamics can answer the physical question. A petrol mower's shaft work comes mainly from the chemical work potential in its fuel. Natural processes formed that fuel; extraction, refining and transport made it available. The machine channels the energy. Billy's body, knowledge and decisions direct it. Materials wear out and waste leaves the process. Labour alone does not exhaust this physical story, and neither does an abstract fund called capital.

Even if Keen were completely right, however, the machine would not manufacture its owner's title deed. The shareholder is not the mower, the fuel, the waterfall, the worker or the geological process. Expanding the list of physical contributors cannot turn all of them into the personal achievement of whoever holds a security.

The useful conclusion is therefore modest and strong. Marx helps keep physical usefulness, value and price distinct; this argument adds entitlement as a further question. Keen is right to ask whether Marx's labour-only result is protected by its definition. Thermodynamics can describe the material dependencies without pretending to set prices. Property must still explain why one person receives the money left over.

Cambridge removed the aggregate-capital alibi. Austrian economics separated waiting and judgment from physical productivity, then left ownership to property theory. Marx separated material wealth from value, but reserved new value for labour. We can now return to the mower and ask what physically makes it move.

The power source capital did not create

Return to Billy's mower. So far it seems to have three participants: Billy, the machine and the person who paid for it. But the machine remains silent until a fourth participant arrives in a petrol can or a charged battery.

Petrol contains chemical work potential. The mower converts some of it into a turning blade and loses the rest as heat, noise and exhaust. Billy supplies purpose, skill and control. The investor may have enabled the purchase. These are all real roles, but they are different roles.

Cambridge did not show that machinery is inert. It showed why unlike machines cannot be melted into one price-free quantity of "capital" and then used to explain the return on capital. Austrian theory says interest is not the machine's physical product. Marx says physical usefulness and

monetary value are different things. Thermodynamics can now tell us what is happening in the production process itself.

Draw a boundary around the workplace. What crosses it?

- particular materials and components;
- fuels, electricity and other energy carriers;
- workers, carrying metabolic energy, learned skill and purposes;
- particular machines and infrastructure;
- information, designs and instructions embodied in people and media;
- products and services, emissions, waste heat and worn equipment.

The process can be represented schematically as:

$$y = T(m, x, k, l, I; E)$$

Here **m** is the list of material flows, **x** the exergy flows, **k** the particular tools and machines, **l** labour, **I** information and organisation, and **E** the surrounding environment. In plain English, output depends on all of these things. The notation deliberately contains no single blob called capital. A mower and a server remain different objects with different needs.

The First Law says energy is conserved. A mower does not create energy; it converts the chemical energy of fuel or the electrical energy of a battery into rotation, motion, sound and heat. A worker does not create energy either; a living body maintains itself using chemical energy from food. Production changes the form, location and organisation of matter by drawing on these energy transformations.

Conservation alone is not enough. One kilojoule of room-temperature heat cannot do everything one kilojoule of electricity can do. For assessing an energy carrier's capacity to drive a process, the relevant thermodynamic quantity is **exergy**: the maximum useful work obtainable as a system comes into equilibrium with a specified environment. Exergy measures work potential, not energy quantity alone.

For a steady process, after the fuel and product have been defined, the compact exergy balance is:

$$\begin{aligned} X_F &= X_P + X_L + X_D \\ X_D &= T_0 S_{\text{gen}} \geq 0 \end{aligned}$$

Read the first line as bookkeeping for work potential. The input X_F becomes a desired effect X_P , leaves unused as X_L , or is destroyed as X_D . In the second line, T_0 is the absolute temperature of the reference environment and S_{gen} is the rate of entropy generation. Their product is the rate at which irreversible processes destroy the capacity to do useful work. A changing process must also count exergy stored inside the boundary. [George Tsatsaronis's standard nomenclature](#) gives the full engineering treatment.

Neither equation contains an owner, a share certificate or a dividend. That is not political rhetoric. Those items simply have no physical unit that belongs in an exergy balance.

Engineers must first say what lies inside the boundary and what counts as the product. A turbine delivers measurable mechanical work. A haircut or a cut lawn instead delivers a desired change. For such services, exergy use can be reported per defined result - for example, per hectare maintained to an agreed standard. Losses at different stages may also be reported separately. Exergy destruction must not be counted twice: it is part of what happens to the input, not a second input.

This gives us a precise account of what a machine contributes. It can:

- make a transformation physically possible;

- increase the rate or scale at which it occurs;
- direct an exergy flow more accurately;
- reduce avoidable exergy destruction;
- substitute one material or energy carrier for another;
- embody knowledge so that a technique can be repeated.

Capital goods are productive in exactly this concrete sense. They are durable configurations of matter, themselves made through past labour, materials and exergy, that channel present flows into useful work. As equipment wears, its capacity may degrade and maintenance or replacement requires fresh throughput. That physical requirement is real, but monetary depreciation is an accounting estimate that may also reflect age and obsolescence; thermodynamics does not determine the correct charge.

Capital goods may store, transmit or convert exergy; they do not create it from nothing. **Concrete capital goods arrange physical flows; financial capital secures command over resources; legal title determines who may use them and who receives the proceeds.** These are three different roles.

The shareholder register contributes no term to the exergy balance. Hold the mower, operator, fuel, technique and working conditions fixed, and the same grass is cut whether the shareholder is Billy, an investor, a cooperative or a public body. Ownership may later affect access, incentives, maintenance and decisions, so institutions can have indirect causal effects. The title itself is nevertheless an instruction about control and distribution, not fuel in the engine.

Useful work and the material basis of output

The relevant bridge from energy to production is **useful work**: an energy service actually delivered after conversion. Electricity turning a motor, diesel moving a van and food sustaining muscular work are not merely costs on a monetary ledger. Without their work potential, the corresponding production process cannot occur.

This is more than a metaphor. Robert Ayres and Benjamin Warr's [research](#) found that adding useful work improved one long-run model of economic growth. Steve Keen, Robert Ayres and Russell Standish developed [another model](#) in which energy is necessary to both labour and machinery. These studies do not prove that energy has one exact share of economic value, or that it explains every part of growth left unexplained by standard models. They do show why energy's low price can badly understate its physical importance.

Their crucial insight does not depend on accepting every aggregate specification: a small cost share is not proof of a small causal role. Oxygen is usually free and therefore has no factory cost share; production would still stop without it. Likewise, cheap energy can be essential to labour and machinery even when its price is a small part of revenue.

The thermodynamic account also explains why the usual substitution story has a hard physical limit. Substitution and efficiency can reduce throughput, sometimes dramatically. Virgin extraction can approach zero for a particular output through reuse, recycling or drawdown of existing stocks; that does not remove dependence on material stocks or on exergy for collection, separation and reprocessing. No specified material transformation can occur with every required material and exergy input set to zero, and more equipment itself requires materials, construction energy, maintenance and eventual replacement.

The result is not "energy alone creates everything." Workers choose ends, exercise judgment and coordinate action. Knowledge changes which conversions are possible. Institutions determine access and incentives. Materials are not reducible to energy, and useful output is defined relative to human purposes. The claim is both stronger and narrower:

No production without matter and exergy; no directed economic production without labour, knowledge and organisation; no automatic entitlement created by the title to any of them.

The fossil surplus hidden inside "capital productivity"

This is the hinge the orthodox story obscures. Much of what appears as the productivity of industrial capital is the productivity of a **powered machine**, and a large part of the power has historically come from fossil fuels.

Take the engine out of the landscaping example and the mower becomes inert structure. Put fuel through the engine and a compact stock of chemical exergy becomes shaft rotation, blade motion and locomotion. Billy's labour supplies purpose, control and adaptation; the mower supplies a repeatable conversion mechanism; the petrol carries chemical exergy, a fraction of which the engine converts into shaft work while the remainder is destroyed by irreversibility or leaves in exhaust and cooling losses. The service is jointly produced. It is not intelligible as the independent product of an abstract stock of capital.

The magnitude matters. The US Energy Information Administration reports a [heat content of 120,214 Btu](#) per US gallon of motor gasoline. That is 126.84 megajoules per US gallon, or 33.51 megajoules per litre - so 34 MJ/L is sound rounding. This is **energy content**, not a direct measurement of exergy; gasoline's chemical exergy is of similar magnitude but depends on composition and the declared reference environment. An engine converts only a fraction of the fuel's exergy into shaft work. Even after those losses, a small fuel volume allows a powered machine to deliver mechanical work at a rate and duration far beyond unaided muscle.

Where did that capacity come from? Coal, oil and gas are concentrated stocks of chemical work potential formed from ancient organic matter through geological processes over immense periods. Extraction, refining and distribution require present labour, equipment and exergy. They transform a geological feedstock into accessible, usable fuels and may alter its composition and quality; they do not create the geological stock, and any exergy they add comes from other present inputs. Geological formation time is not a current production cost recorded in the fuel price.

Yet the monetary account records fuel only at its purchase price. That price may cover extraction, refining, transport, taxes, market power and some resource rent. It does not automatically charge for the full depletion of a non-renewable inheritance, the use of the atmosphere and ecosystems as carbon sinks, or the damage shifted onto others. The GBP 10 input line in Billy's accounts therefore cannot be read as a physical measure of fuel's contribution or as proof that every affected party has been compensated.

Two-factor value-added models make the disappearance easier. Energy is often treated as an intermediate purchase and deducted before value added is divided between labour and capital. Changes in energy quantity, quality or conversion efficiency can then appear statistically as higher measured labour or capital productivity, or in an unexplained residual; the accounting convention alone does not identify how much. Because the machine is visible and owned while the natural gradient is cheap, buried or treated as background, the owner receives narrative credit for work done by the entire fuel-machine-worker system.

The same fossil inheritance sits upstream of the machine itself. Mining and smelting its metals, firing cement, manufacturing components, building roads and transporting the equipment all require cumulative exergy. The capital good is not an alternative to resource throughput; it is partly a durable result of earlier throughput and a device for directing more of it.

Fossil exergy can therefore support an economic surplus without being the same thing as profit. Consider the whole supply chain: wells, mines, pipelines, refineries, transport and supporting equipment. If the usable exergy delivered by that chain exceeds the exergy consumed in building and running it, the difference is available to power the rest of the economy. The fuel's own

chemical exergy is left out of the cost side here, because including it on both sides would count it twice. Prices, demand and property rules then decide whether this physical surplus becomes monetary profit and who receives it.

So it would be wrong to say that a GBP 35 profit is literally 35 pounds' worth of conserved energy. It is right to say that production on this scale draws on a natural exergy endowment, prominently fossil in this case. The fuel's small monetary cost share does not measure its physical indispensability, its exergy throughput or its environmental effects.

The argument is not confined to fossil capitalism. Renewable flows, nuclear fuels, fertile soils, hydrological cycles and ecological sinks raise their own questions of access and inheritance. Fossil fuel makes the relationship unusually stark because a finite stock accumulated over geological time is extracted, degraded in minutes and converted through owned machinery into privately claimed revenue.

Much of the physical work casually credited to "capital" is performed by energy flowing through a machine under human direction. How much this explains monetary profit is a separate empirical question. The machine deserves causal credit as a converter. The owner does not thereby become the author of the fuel, the atmosphere or the resulting joint product.

Zooming out: the mower brings a supply chain with it

The factory gate is not the beginning of the story. The mower arrives with steel, plastics, electronics and a history. Fuel arrives only after exploration, extraction, refining and transport. Workers arrive because food, housing, health and education sustained their capacities. Waste leaves for an atmosphere, river, soil or treatment system.

Cumulative exergy consumption widens the boundary and traces the direct and indirect primary exergy required to deliver a product or functional service. Ecological cumulative exergy can widen it again to include ecosystem work involved in producing biomass, cycling water, maintaining soils, pollinating crops and assimilating wastes. At a planetary-surface boundary, the main driving exergy flows are solar radiation, deep-Earth heat and tides. Human economies also draw down stored fossil and nuclear fuel stocks.

This accounting reveals three facts that a money ledger can conceal:

1. current output rests on a long upstream chain of material and energetic transformations;
2. environmental stocks, flows and waste sinks make productive activity possible without necessarily receiving a market payment;
3. costs can be shifted outside the firm's accounts while remaining inside the physical system.

It does not turn joules into pounds. The result changes with the reference environment, system boundary, technology and rule for allocating joint inputs among co-products. Hau and Bakshi's [ecological cumulative-exergy framework](#) expressly treats it as a measure of resource requirement, not a proof of economic value.

The phrase "Exergy Theory of Value" therefore needs a precise meaning. It cannot be a one-variable rule under which exergy mechanically fixes exchange value: two goods with equal cumulative exergy can command different prices, and a beloved letter may have enormous meaning with little physical throughput. It is strongest as the claim that material production has a biophysical substrate, that exergy gives a common measure of work potential and cumulative primary-resource exergy, and that market accounts often omit unpriced ecosystem services and external damage.

Call it an **exergy theory of production and physical cost**, not a one-variable theory of price. No exergy, no production. But exergy alone does not tell us what people want or who should own the result.

A genuine biophysical surplus

In an energy-supply chain, declare one boundary, reference environment and accounting period. Let X_{gross} be the exergy of the usable energy carriers produced at the output boundary, and let X_{invested} be the auxiliary direct and indirect exergy consumed to build, maintain, operate and decommission the supply chain, excluding the exergy of the environmental stock or flow being harvested:

$$\begin{aligned} X_{\text{net}} &= X_{\text{gross}} - X_{\text{invested}} \\ R_X &= X_{\text{gross}} / X_{\text{invested}} \end{aligned}$$

When $R_X > 1$, the chain delivers more usable exergy than it consumes within the chosen boundary and accounting rules. If $R_X = 5$, for example, each unit invested delivers five units gross and leaves four units net for the rest of the economy. This is an accounting surplus; it does not prove that the output can replace every specialised material or energy input needed to reproduce the chain. The ratio resembles **energy return on investment** (EROI), but it is not the same as an engine's conversion efficiency. As [EROI protocols emphasise](#), the result changes when the boundary or allocation rule changes. The supply chain does not create the source's work potential. Labour, knowledge and equipment capture and convert exergy supplied by nature, and some of it is unavoidably destroyed in the process.

The same logic extends beyond fuel extraction. Every production network appropriates natural gradients, rearranges materials and uses environmental sinks. A more efficient technique can obtain more desired service from the same input; it cannot manufacture the original gradient from nothing.

This is the material fact at the centre of the vampire metaphor. The present title-holder did not make the sunlight, mineral body, atmosphere or biosphere on which the process depends, and almost never created all the inherited knowledge it uses. A title can control access to these conditions and to the produced equipment that channels them. It cannot be their physical author.

Physical surplus is not monetary profit. A firm can waste exergy and remain profitable because it has market power, subsidies or free disposal of pollution; it can be exergy-efficient and lose money because demand is weak or prices collapse. Thermodynamics explains feasibility, physical dependence and conversion efficiency. Exergy accounts one dimension of resource use and degradation; material-stock, emissions, toxicity, biodiversity and scarcity accounts are still required. Prices emerge from demand, supply, expectations, institutions and market power. Property rules determine who may claim the monetary residual.

The two ledgers of capitalism

The clean way to join the physical and economic arguments is to keep their ledgers separate long enough to see the bridge.

Physical ledger	Monetary-property ledger
Materials and exergy cross a declared boundary.	Purchases are recorded at market or administered prices.
Workers, knowledge and organisations direct transformations.	Labour is recorded as wages or salaries under a contract.
Particular machines channel flows and wear through use.	Produced assets generate depreciation charges and may earn rentals.
Useful products or services, by-products, waste and emissions emerge.	Sales become revenue; priced costs are deducted.
Energy balances; exergy is transferred, lost or destroyed.	Money values are neither conserved nor determined by exergy.
Ownership title contributes no physical flow.	Ownership determines exclusion, control and the residual claimant.

For a firm, the monetary accounts can be written schematically as:

$$\begin{aligned}\text{EBIT} &= \text{revenue} - \text{wages} - \text{intermediate inputs} - \text{other operating costs} - \text{depreciation} \\ \text{net income} &= \text{EBIT} - \text{interest} - \text{taxes}\end{aligned}$$

Dividends are distributions of net income or retained earnings, not expenses in arriving at profit. Economic profit additionally deducts the opportunity cost or normal return on equity. Which residual is meant, which items appear, how they are valued and who receives the remainder depend on accounting rules, contracts, market prices and law. Profit is therefore a monetary residual from a biophysical process under an institutional system. It is not an extra quantity of energy and it is not an exergy "product."

A simple ownership thought experiment makes the distinction decisive. Keep the physical ledger fixed and replace indefinite common equity with a bank loan, a terminating revenue share, cooperative finance or public credit. The mower performs the same transformation. What changes immediately is the schedule of claims, the distribution of risk, the right to decide and the destination of the residual. Different arrangements may change later behaviour, but that is an institutional effect to be demonstrated - not evidence that an absentee title was hidden inside the production process.

Machines are exergy converters. Titles are tollbooths.

From natural surplus to resource rent

The connection can be made operational without pretending that joules have a natural price. The United Nations System of Environmental-Economic Accounting estimates **resource rent** by starting with adjusted gross operating surplus and deducting both fixed-capital consumption and a stipulated normal return to produced assets:

$$\text{Resource rent} = \text{GOS_RR} - \text{consumption of fixed capital} - \text{return to produced assets}$$

where GOS_RR is SNA gross operating surplus, with gross mixed income where applicable, minus resource-specific extraction subsidies plus resource-specific extraction taxes.

Labour and intermediate inputs have already been deducted in reaching operating surplus. The remaining estimate is intended to capture the monetary return associated with controlling an environmental asset. The [UN SEEA framework](#) uses this method for resources such as minerals, energy resources, timber and water.

The estimate is assumption-sensitive, especially to the chosen normal return. It is not a thermodynamic identity, and it isolates natural-resource rent only for the relevant resource activity; it cannot identify a resource-rent component inside Billy's GBP 35 without sector-specific physical and monetary data. That is precisely why the two-ledger method matters: exergy accounting quantifies work potential carried by declared resource flows and the loss or destruction of that potential within a boundary; separate stock and impact accounts measure depletion and ecological harm. Rent accounting estimates which monetary residual is associated with control of the resource. Neither number is secretly the other.

This gives the anti-capitalist argument a firm first foothold. The owner of an oil field did not produce the oil's chemical exergy. The owner of a hydro site did not produce gravity or rainfall. The owner of a scarce location did not produce the surrounding city. Property law permits an owner to exclude others and charge for access to these unproduced conditions. Where the resulting rent is retained without an equal claim or compensation for those excluded, the owner captures a natural and social inheritance rather than receiving a product the owner created.

Property is the missing cause

Resource rent gives the argument its narrowest case: the owner of an oil field did not make the oil. To extend the argument to profit from produced assets, the rule of property must be brought into the open.

In the Proudhonian sense used here, **property** does not mean a coat, a toothbrush or the tools someone personally uses. It means an enforceable power to exclude others from productive resources and collect recurring income from their use. Proudhon's [What Is Property?](#) attacks the idea that labour, occupation or law automatically creates an unlimited right of that kind.

"Property is theft" is therefore not the claim that every owner is a burglar. Here **theft** means taking an income stream from people with the stronger justified claim, when they have not validly transferred it. Passivity, luck and large earnings are not enough to prove that. The argument needs every link in the following chain.

- 1. Nature is not the owner's product.** Owners may improve resources, and those improvements can deserve payment. They did not create the original minerals, sunlight, rainfall, atmosphere or biological systems.
- 2. Production is joint.** People, knowledge, organisations, infrastructure, particular tools, materials and exergy work together. Cambridge shows why class shares cannot generally be justified by the marginal products of two aggregate factors called labour and capital.
- 3. A title is not a physical input.** If the mower, fuel, worker and method stay the same, changing the shareholder adds no matter, energy, skill or information.
- 4. A title is still powerful.** Law makes exclusion effective. It shapes everyone's options and tells the money ledger who controls the assets and receives what remains.
- 5. Common inheritance.** The moral rule used here treats unproduced natural opportunities and shared waste sinks as a common inheritance. Exclusive use therefore requires collective permission or compensation to those excluded.
- 6. Reciprocity.** Supplying resources, doing work and accepting enforceable exposure to loss can justify payment. A finance payment should cover the amount advanced, waiting, difficulty of resale, useful services and the investor's own risk as it could reasonably be valued when the deal was made. Company debts and workers' losses cannot simply be relabelled as shareholder sacrifice.
- 7. The anti-rentier rule.** The benchmark finance claim is fixed in advance and capable of discharge. It may vary with success or failure, use a redemption formula, end after a stated revenue share, or pay an annuity with a finite value when issued. It is not simply whatever terms the parties signed. Once the benchmark has paid for the advance and its genuine burdens, bare ownership supplies no extra claim on the residual. In a thin private market there may be no single exact "fair" number: valuation evidence estimates the burden, while this moral rule chooses the kind of right that may be granted.
- 8. A stronger residual claimant.** The remaining income must belong, under the chosen moral theory, to specified active producers or common claimants. Economics and thermodynamics do not choose those people for us.
- 9. No valid surrender of that claim.** Either the stronger claimants did not meaningfully transfer the residual, or open-ended control over future joint production is considered something they cannot permanently sell. A signature alone does not prove bad consent, but neither does it settle every question about power and alienability.
- 10. Evidence in the actual case.** After all work, services, costs and genuine finance risks are counted, evidence must show that a payment remains because of title or bargaining power alone. A charge of structural leverage also needs evidence about the options available when the bargain was made.

11. Conclusion. Only when steps 5 through 10 are also true does a title-only residual count as wrongful appropriation - "theft" in this stated moral sense, whether or not the criminal law uses that word.

Time by itself does not decide the matter. A one-off payment can buy an annuity that lasts indefinitely but has a finite value when purchased. The anti-rentier objection is not simply that payments continue. It is that, after the benchmark finance burden has been fully rewarded, an extra claim survives only because the owner retains the power to exclude. That claim needs its own defence. It cannot be derived from the old advance or from the machine's output.

The different disciplines now have exact jobs. Thermodynamics supports steps 1 and 3 but says nothing about moral desert. Cambridge blocks the aggregate-productivity story in step 2. Law makes step 4 a fact. Steps 5 through 10 are moral principles and factual tests that must be defended separately. The conclusion follows only if all of them hold.

That gives two possible conclusions:

- **Narrow:** taking resource rent from unproduced nature and shared waste capacity, without common permission or compensation, is theft under the common-inheritance principle.
- **Broad:** profit received merely for ownership of produced assets is also theft under the stronger anti-rentier rule, provided that the stronger claimants did not validly give away the residual.

The broad conclusion is deliberately conditional. Making its moral premises visible is a strength. It stops a political choice being dressed up as a result of calculus.

Risk is compensable. It is not a title deed

The strongest objection to the anti-rentier rule is simple: "The investor accepted the downside, so the investor deserves the unlimited upside." The symmetry sounds fair. In most companies, it does not exist.

Ordinary shareholders can lose everything they paid for their shares. That can be painful and deserves to be taken seriously. But they do not normally inherit the company's unpaid debts. Their loss is capped while the possible gain is not. And even genuine risk does not tell us that the only proper contract is an indefinite share carrying both profit and control.

A better defence of equity avoids the claim of unlimited personal loss. It says that equity absorbs the first losses, leaves money committed to the business, supports incentives and gives someone useful control when contracts cannot anticipate everything. These can be real economic benefits, as the [property-rights theory of incomplete contracts](#) argues. If the shares were validly issued and transferred, a property theory may also say that the claim should last as long as the company. Limited liability does not answer that entire case. It answers the narrower fantasy that unlimited gain is the reward for unlimited personal loss.

Start with the payoff. In a simplified one-period example, let A_T be the company's asset value at settlement after any earlier distributions, D_T its senior obligations, q the investor's ownership fraction and P_0 the price paid for fully paid shares bought without borrowed money. The investor's final equity payoff is:

$$E_T = q \max(A_T - D_T, 0).$$

If C_T is the total of non-negative cash distributions received along the way, the investor's total gain is:

$$G_T = C_T + E_T - P_0 \geq -P_0.$$

The important part is the final inequality: $G_T \geq -P_0$. The investment can fall to zero, but the shareholder cannot lose more than the finite sum paid, unless some extra obligation has been assumed. There is no matching ceiling on the upside. This resembles the payoff of an option, as

formalised in Merton's [model of corporate debt and equity](#). Equity supplies **first-loss capital**. It does not ordinarily absorb every loss the business creates.

The law creates that asymmetry. Under [section 3\(2\) of the Companies Act 2006](#) and [section 74\(2\)\(d\) of the Insolvency Act 1986](#), a holder of fully paid shares normally owes no further contribution when the company is wound up. If Billy's investor buys GBP 5,000 of fully paid shares without borrowing or giving a personal guarantee, the maximum loss **as a shareholder** is GBP 5,000. When the shares reach zero, the company's unpaid deficit does not become the investor's personal bill. Suppliers and other unsecured creditors may go unpaid; workers may lose earnings and specialised skills; public and ecological costs may land elsewhere. The risk has not disappeared. Law has distributed it among different people.

There are real exceptions: partly paid shares, personal guarantees, borrowed money used to buy the shares, promises of further funding, some unlawful distributions, fraud, and personal liability assumed in another legal role. Those extra risks should be identified, priced and compensated. They cannot be used to invent "uncapped downside" for a shareholder who never accepted them. Personal bankruptcy is not painless either; it can consume assets and leave some debts in place. The argument does not need the claims that every failure is mismanagement or that every investor can sell before trouble arrives. Both claims are sometimes false.

An indefinite share is not the same thing as an indefinite personal duty to keep funding the company. [Shares are normally transferable subject to the company's rules](#), so the claim may continue while its holders change. Selling is no magic escape: bad news may already have destroyed the price, buyers may vanish, and a personal guarantee can survive the sale. The smaller point is enough. A claim can last indefinitely while one holder's cash exposure remains capped and potentially transferable.

Genuine risk still deserves a genuine price. In a standard model, the value today of a claim Q with uncertain future payments X_t can be written:

$$V_0(Q) = E_0[\text{sum from } t=1 \text{ to } T \text{ of } M_t X_t]$$

The expectation E_0 uses the information available today, T is the model's chosen horizon, and M_t discounts delay while giving different weight to payments arriving in good and bad states of the world. In a thin private market there may be no single uncontested "fair" value, and the observed GBP 5,000 price does not prove that the bargain was competitive. A rare hundredfold winner may be needed to cover many failures. Billy's 642.6 percent first-year return is therefore not, by itself, proof that the deal was unfair. A bounded finance claim can vary with events; it need not have the same cash ceiling in every possible future. The rule needs a defined value and scope when the bargain is made.

That concession still does not derive indefinite common equity. A risk-adjusted loan, guarantee fee, terminating revenue share, redeemable preference share, insurance contract or time-limited profit share can all reward uncertainty. They create different incentives and behave differently in success and failure; whether one could fund Billy on acceptable terms is an empirical question. Nothing in risk theory says the necessary package must combine an indefinite residual, voting power, transferability and a claim on every later success. Risk may warrant a price. It does not write a title deed.

The share price creates a subtler circle. Suppose the investor's stake later sells for GBP 160,650. A new buyer really pays that sum and risks losing it. The seller really gives up a valuable asset, and an active resale market can make the original investment more attractive. But the money normally goes to the seller, not to Billy's company. More importantly, much of the price comes from the expected future dividends.

There is nothing circular about valuing a share from its expected payments, control, resale value and risk. The circle appears only when that price is offered as independent **moral proof** of the payments that created it:

title -> expected residuals -> capitalised share value -> risk of losing that value -> justification of title.

In plain language: expected dividends make the share valuable; the risk of losing that valuable share is then used to justify the dividends. That proves an opportunity cost **after the title exists**, not an independent reason why the title should exist. The original GBP 5,000 is a real contribution and must be compensated. A defence based on valid acquisition and consent is not circular in this way; it simply returns the dispute to property and morality, where it belongs.

The shareholder is not the only person at risk. Lenders and suppliers face default. Workers face unemployment, unpaid claims and the loss of specialised earning power. A [study of US corporate bankruptcies](#) found large and lasting losses in employees' earnings. Standard diversified-market theory also says that risk an investor can cheaply spread across many firms does not automatically earn a premium, although Billy's private investor may be concentrated and unable to sell. The facts must be measured. "The shareholder bears the risk" is not a complete map of the downside.

The surviving defence is a separate rule of property: a valid finite exchange may create an indefinite, saleable residual right even when the buyer's loss is capped. That position is coherent. It must defend the starting ownership, the quality of consent, the ability to sell claims over future joint production and the system of limited liability. It cannot rely on an imaginary symmetry between unlimited loss and unlimited gain.

Corporate equity is not unlimited liability rewarded by unlimited upside. It is limited downside packaged with an indefinite, transferable residual claim. Risk may warrant a price; it does not, without another premise, warrant a dynasty.

How a temporary GBP 5,000 shortage can become 51 percent for as long as the shares survive

The investor need not create half the lawns. The investor need only control a gate Billy cannot pass.

This is **structural leverage**: the power to turn someone else's lack of options into favourable terms. Payment for risk and payment for leverage can exist in the same deal. The job is to separate what rewards money, delay, work and genuine loss from what rewards control of the only usable route into business.

This accusation must be proved case by case. A person can reject open-ended equity on anti-rentier grounds even if its price was competitive. To call part of the price a liquidity rent requires additional evidence that Billy really had weak alternatives when the deal was made.

Credit does not always behave like a clean textbook auction. Stiglitz and Weiss showed why [credit rationing](#) can persist even when banks compete: charging more can attract riskier borrowers and encourage riskier behaviour, so a bank may refuse a loan rather than keep raising the rate. That proves the possibility, not Billy's case. One rejected application tells us only about that lender, that application and those terms. We still need to investigate the real alternatives.

A genuine bottleneck means Billy had no realistic loan, competing investor, supplier credit, public credit or way to delay the purchase. The property system creates the lever - the right to withhold access. Market conditions determine how hard that lever can be pulled. Calling the investor a local monopolist still requires evidence about the relevant market and Billy's alternatives; one bank saying no is not enough.

The mechanism has four parts.

1. **A liquidity tollbooth.** Billy has the skill and the customers but cannot cross a GBP 5,000 gap. The investor can withhold the money that opens the gate. Scarcity makes finance valuable; it does not make the financier a physical producer of lawns.

2. **A dated payment becomes a durable claim.** The money may buy a long-lived asset, remain exposed to loss and help solve incentive problems. Its economic service need not be momentary. But ordinary shares have no automatic "paid enough" switch. The 51 percent can continue for as long as the company and the shares do. Whether a terminating contract could offer the same commitment is a factual question.
3. **Weak alternatives weaken bargaining power.** If Billy's choice is harsh terms or no business, the investor may demand more than fair payment for risk, delay, difficulty of resale and services. In this example, the deal gives the investor majority voting rights and GBP 17.85 of every distributed GBP 35 before a lawn is cut. Real control depends on the company's articles and agreements, and no dividend is automatic; 51 percent is not magic in every company.
4. **Law remembers the old shortage.** The share stores that first bargain in an enforceable, usually saleable title. It can later be sold, bought back, diluted, altered or ended with the company. But unless somebody takes such an action, it has no repayment trigger. A short-lived shortage can therefore govern income years later. A later buyer pays the seller for the claim and bears its future risk; that transaction finances the seller rather than Billy's company, while preserving the original residual right.

The possible extra return can be written without pretending that one successful year proves anything. Let Q mean the whole 51 percent package of uncertain dividends and control. Let $V_0(Q)$ be a careful estimate of what that package was worth when the deal was made. It should use independent cash-flow and risk valuation, together with genuinely competitive or realistic alternative financing terms - not merely similar deals that may contain the same imbalance. Let S_0 include the value of advice, management, guarantees, monitoring, commitments and transaction costs. Then the possible investor surplus is:

$$\text{Lambda}_0 = V_0(Q) - \text{GBP } 5,000 - S_0.$$

If Lambda_0 is credibly positive, the package was worth more at the start than the investor's cash, work and costs. Even then, the gap is not automatically rent. It may reflect a missed service, useful governance, information, a genuine business advantage or a bad valuation. Only the part caused by control of Billy's weak alternatives counts as bargaining or liquidity rent. The estimate must use what could reasonably have been known when the deal was made, not the happy result seen afterwards.

"Monopoly rent" is a finding, not a nickname for every large return. We would need evidence about other offers, comparable start-up deals, the chance of failure, guarantees, services, incentive effects, costs and bargaining history. But once those factors have been counted, calling every remaining pound a "risk premium" proves nothing. It merely assumes that the disputed bargain was competitively priced.

The share is a claim against the company, not ownership of Billy. That legal distinction matters. Yet the income comes from future production using Billy's continuing work and knowledge, equipment, public infrastructure, materials and nature's exergy. After the investor's real contribution and every other explanation have been counted, any remaining Lambda_0 caused by control of Billy's financing options comes from position, not production. When the shortage is temporary but the share is not, a temporary power to say **no** becomes a continuing power to say **mine**.

The strongest replies and alternative accounts

None of the standard replies restores the classic aggregate chain. Some identify genuine contributions that deserve direct treatment; others offer a different moral theory or, as with Marx, an alternative account of profit rather than a defence of capitalist entitlement.

Defence	What it establishes	What it does not establish
Risk	Exposure to loss, valued before the outcome is known, may justify a risk-adjusted expected return; a large realised payoff can still have had a modest initial value.	A fully paid limited-liability share ordinarily caps the holder's loss while leaving residual upside uncapped. Risk neither selects an indefinite, transferable ownership bundle nor turns the company's and creditors' losses into shareholder sacrifice.
Scarce finance	A funding bottleneck can make finance indispensable and give a financier bargaining power.	Indispensability does not identify a competitive price. Terms may contain a liquidity rent; proving that requires valuation from the time of the deal and evidence about realistic alternatives.
Waiting or time preference	Otherwise comparable future receipts may be discounted relative to present receipts; a contingent perpetuity can have a finite present value.	The discount prices a dated claim conditional on its cash flows and rights. It does not make interest a machine's physical product, nominate the claim's owner, select 51 percent equity or prove that the underlying title is just.
Entrepreneurship and management	Discovery, coordination, monitoring and judgment are real work. Austrian entrepreneurial profit or loss records superior or inferior anticipation under uncertainty.	A forecast gain is not pure interest or a guaranteed risk premium, and calling managerial work "capital" does not make passive title productive. Pay the work as work, including contingent pay where appropriate.
Saving and finance	Pooling resources across time can enable a project that otherwise would not occur.	Enabling production is not identical to physically producing each later surplus, nor does it settle the duration and scale of the claim.
Monetary calculation	Money prices help compare very different plans using demand, scarcity and forgone alternatives; an exergy balance cannot do this.	Calculation depends on purchasing power, prices and titles. It does not make financial capital a physical input, price every external cost, validate starting ownership or establish indefinite outside equity as the only workable system.
The productive machine	Removing the mower may reduce output; its services matter.	What the mower adds is not the absentee owner's personal contribution, and the machine does not issue its own deed of title.
Disaggregated general equilibrium	It can price particular goods at particular dates and under particular future events without aggregate K. Its existence and conditional-efficiency results do not require the Clarkian aggregate.	It does not restore a one-way capital-demand schedule, make interest the marginal product of one capital factor, equate an equity residual with a machine rental, or justify the starting resources and titles supplied to the model. Showing that an equilibrium exists also does not prove that a real economy will move towards it.
Rothbardian valid title	If the investor's GBP 5,000 is justly owned, the equity interest can validly be sold, Billy consents validly and no stronger claim or uncompensated harm exists, a voluntary transfer can justify the 51 percent title within that theory.	The justice of the starting distribution, original acquisition, ability to transfer the claim and background constraints is assumed rather than derived by time preference, Cambridge or thermodynamics. Rejecting any premise requires a property argument, not a production equation.
Marxian surplus value	It provides a non-marginalist account in which living labour creates new value and capital ownership appropriates and redistributes surplus value.	The claim that only labour creates value remains disputed; Keen's machinery challenge does not by itself prove a monetary energy theory. Either way, a machine's productivity does not derive the owner's title.
Voluntary contract	The bargain may improve both parties' positions relative to their available alternatives.	Mutual benefit does not prove a unique fair division or validate the prior exclusions that shaped those alternatives.
Incentives	Some ownership rules may encourage maintenance, innovation and investment.	This is a comparative institutional claim requiring evidence. Loans, cooperatives, public investment and terminating claims can also create incentives without indefinite absentee dominion.
Subjective value	Demand, scarcity and expectations help determine prices.	Prices do not cancel mass and energy balances or show that the recipient of a price morally created the physical product.

The replies therefore change the accounting question. Do not ask how much "capital" in the abstract deserves. Ask what resources were transferred, for how long; what losses were

genuinely borne; what work was performed; what alternatives existed; what ecological costs were displaced; and what payment would proportionately cover each item. Whatever remains solely because a title can be enforced is the property-income component under dispute.

Billy's business through both ledgers

Return to the landscaping firm.

On the physical ledger, petrol or electricity powers the equipment; food sustains Billy; materials and spare parts maintain the tools; the mower and van channel these flows; Billy's skill and decisions direct them; lawns are altered; noise, heat, emissions, clippings and worn components leave the process. If the equipment is petrol-powered, much of the immediate mechanical work comes from fossil chemical exergy supplied by nature and made accessible by an extraction-and-refining chain. The invoices do not contain enough physical data to calculate exergy per serviced hectare, but the dependencies are unambiguous.

On the money ledger, customers pay GBP 180,000. With corporation tax set to zero and the stated costs paid, GBP 63,000 is lawfully distributed: GBP 30,870 to Billy and GBP 32,130 to the investor. The investor has received GBP 27,130 more in cash than the original outlay, before personal tax. The remaining shares and future dividends may still fall to zero, but that would not take back cash already received. The payback matters when judging the finance bargain. It does not prove by itself that fair risk compensation is complete, and it does not turn the continuing 51 percent into a physical output.

Now hold the physical operation fixed and alter only the financing:

- a GBP 5,000 term loan ends after principal and interest are paid;
- a revenue share ends after a stated multiple is returned;
- redeemable preference shares end on agreed terms;
- a cooperative fund recycles the surplus among users;
- public credit charges a financing cost while leaving the residual with the worker or community;
- indefinite common equity gives the investor an open-ended residual and governance claim.

Nothing in the mower selects the last arrangement. The alternatives distribute commitment, risk, control, incentives and future income differently; whether any would fund this project on acceptable terms requires evidence. The physical technology underdetermines the choice.

Judging the bargain requires evidence from the time it was made: the chance of failure, the shareholder's legal exposure, guarantees, promises of more funding, services and costs, incentive effects, comparable offers, control terms and Billy's realistic alternatives. One successful year cannot prove that the original deal was excessive. Cambridge and exergy accounting cannot supply these facts. Pay management as work, exposure to loss as risk and a hard-to-sell investment for being hard to sell. Only an extra return caused by control of Billy's weak alternatives counts as liquidity rent.

The rejected loan proves only that one application failed. It does not by itself prove a market-wide bottleneck, monopoly rent, unjust exclusion or invalid consent. But treating all of the 51 percent as a "risk premium" also needs evidence; we cannot assume a competitive price when Billy's lack of alternatives is the issue. Under the anti-rentier rule, control ends when the benchmark finance claim has been met. If evidence then shows a title-only or bargaining-rent remainder, and the people with the stronger moral claim did not validly transfer it, continued capture is wrongful appropriation in the Proudhonian sense used here.

The accounts tell us **where** the GBP 35 an hour goes. Cambridge shows why an aggregate marginal-product story cannot tell us that "capital" created the owner's share. Austrian theory can price time but must import the title that names the payee. Marxian theory treats industrial

profit, interest and rent as divisions of surplus value, but its labour-value rule cannot describe the energy process. Thermodynamics tells us what physically performs the service. Property law tells us why the investor receives the cheque.

The argument in compact form

The full reasoning can be stated in fifteen short steps. The first twelve are economic and physical findings. The last three add the moral premises needed for a verdict.

1. The classic defence says that a measurable quantity of capital κ adds output at the margin and therefore earns the normal return.
2. Unlike machines cannot generally be added into one physical quantity. Adding their prices gives a money value, not a physical stock.
3. Those prices depend partly on wages and the rate of return. The return therefore helps measure the "capital" that is then used to explain the return.
4. Reswitching and capital reversing prove that there is no universal ladder from more capital per worker to a lower return.
5. Disaggregated general equilibrium avoids the problem by pricing particular goods at particular dates. That is valid, but it abandons the single κ and does not turn a machine rental into a normal class return.
6. In those models, the shareholder's fraction is supplied as an ownership fact. The production equations do not generate or justify it.
7. Austrian economics can explain discounting across time and gains from uncertain judgment without aggregate κ . Its defence of the owner still comes from a separate theory of valid title and consent.
8. Marxian economics says that labour creates new value while machines and nature expand material wealth. Keen challenges that boundary, but either answer leaves physical contribution, monetary value and ownership as different questions.
9. Physical production uses matter and exergy, together with labour, knowledge, organisation and particular tools. Fossil fuel has supplied a large share of the work potential used by industrial machines.
10. A title supplies no matter, exergy or skill. It can still affect production indirectly by controlling access, incentives, finance and decisions.
11. In a limited company, fully paid shares bought without personal borrowing, guarantees or further-funding duties expose the holder, as shareholder, to a finite contractual loss. Their residual upside has no fixed contractual ceiling.
12. Risk, waiting, difficulty of resale, management and useful commitments can all deserve payment. None uniquely requires a permanent, saleable bundle of residual income and control. If weak financing options let an investor obtain value beyond those contributions, the extra part is bargaining or liquidity rent - but that must be proved from the facts known when the deal was made.
13. Nothing above decides who **ought** to own the residual. That requires a moral rule. Rothbardian property theory supplies one answer if its premises about acquisition, consent and transfer are accepted.
14. The rival rule used here gives unproduced nature to the common inheritance, pays real contributions and exposure to genuine risk, and rejects an extra open-ended return for bare ownership once its benchmark finance claim has been met.

- 15.** If the facts reveal a title-only or bargaining-rent remainder, and the people with the stronger claim did not validly surrender it, its continued capture is wrongful appropriation under that rule.

Cambridge removes the aggregate-productivity alibi. Austrian economics prices time but leaves the payee to property theory. Marx exposes appropriation but reserves new value for labour. Thermodynamics reveals the physical process. Law supplies the route by which the money reaches an owner. Moral premises - not calculus - supply the final verdict.

Capitalism is not a theorem

At the end of the day, Billy puts the mower back in the shed. The fuel tank is lighter. The blade is more worn. Billy is more tired. The investor's share certificate looks exactly as it did that morning.

Why, then, does part of the day's residual go to the investor?

There are three different answers.

The **legal** answer is easy. The company issued shares carrying 51 percent of the relevant voting and distribution rights. If the directors lawfully declare a dividend, company law routes 51 percent of it to the holder. The payment is legally valid because an enforceable title says so.

The **moral** answer is disputed. Some people believe that a valid purchase may create an indefinite and transferable residual claim. Others believe that finance should receive a risk-adjusted but terminating reward, after which the residual should belong to workers, users or the community. No mathematical result can choose between those principles.

The third answer mixes an economic explanation with a moral conclusion. Economics can explain why an existing claim commands a return, given time preference, risk, scarcity and a system of property rights. What it cannot supply is a value-free theorem turning that return into the current owner's natural moral entitlement. That stronger answer does not survive.

The Cambridge controversy shows why "capital" cannot generally be measured as one independent physical quantity and then credited with a marginal product that determines its own return. Disaggregated general equilibrium replaces that story with a legitimate theory of particular goods and prices across time. It can explain returns once endowments and rights have been supplied. It does not restore a homogeneous capital factor or justify those endowments and rights. It can price the service of Billy's mower and value a share from expected payments. It cannot turn either result into a theorem that the shareholder physically produced, or morally deserves, 51 percent of every later residual.

Austrian economics supplies a cleaner account of time. A future receipt may be worth less than a present one. Entrepreneurs who judge an uncertain future well may earn gains; those who judge it badly may suffer losses. None of that identifies the rightful owner of the receipt before property theory has done the work. Discounting tells us what a specified claim may be worth. It does not create the claim.

Marx supplies a powerful account of appropriation, while his claim that labour alone creates new value remains contested. Thermodynamics does not settle that argument. It does something both humbler and harder to evade: it identifies the physical dependencies. The mower channels useful work potential. Fuel or electricity supplies the immediate power. Billy supplies metabolism, skill, judgment and direction. An upstream civilisation supplies roads, knowledge, mines, refineries and factories. Nature supplies the original stocks, flows and waste sinks. The title supplies none of these. It determines access and routes the money.

This does not make finance useless. The investor's GBP 5,000 may be the difference between a business and no business. Loss is real. Delay, difficulty of resale, advice, monitoring and commitment can all be costly. Ownership rules may improve incentives, protect investment and make cooperation possible when no contract can cover every future event. Economics can

compare those effects. It can sometimes show that one arrangement is likely to produce more investment, better maintenance or a larger total surplus than another.

Those are **conditional practical arguments**. They depend on evidence, aims and available alternatives. A permanent equity claim might work better in one setting and worse in another. A loan, cooperative fund, public bank or terminating revenue share may sometimes do the job. Showing that an institution has useful effects does not show that its recipients possess a natural entitlement, any more than showing that a tollbooth finances a bridge proves that the toll collector built the river.

That is the limit economics cannot cross on its own. It can explain how a property system works. It can estimate its effects. It can tell us that a bargain made both parties better off than the options they actually had. It cannot infer from those facts that the starting options were just, that the division was uniquely fair, or that an owner has a timeless moral right to whatever the law directs to the title.

Structural leverage makes the distinction visible. The property system gives owners the right to withhold access. Sometimes that power is modest because finance is plentiful and alternatives are real. Sometimes a GBP 5,000 bottleneck lets one person turn a temporary need into a claim lasting as long as the shares. The property system creates the lever; market conditions determine how much can be pulled from it. Calling the result "the return to capital" does not make the leverage disappear.

A community may still choose permanent owner residuals. It may regard them as morally proper, practically useful or simply familiar. That is its political and moral prerogative. The honest description is that it has chosen a property regime with particular benefits, costs and winners - not that a production function discovered the arrangement in nature.

Capitalism was not found in the world like gravity or entropy. It is a legal and political construction. It has often been defended by treating contingent property rules as though economics had discovered them in nature. Once production, pricing and ownership are separated, that supposed necessity vanishes. What remains is a choice about who may exclude, on what terms, and for how long.

The owner's return may be legal. Some may regard it as moral. In particular circumstances it may even be useful. What it is not is the mathematically ordained reward of a naturally productive abstraction called capital.

The fuel supplies the energy. The machine channels it. People perform and organise the work. Property decides who gets the cheque.

Sources and further reading

- John Bates Clark, *The Distribution of Wealth: A Theory of Wages, Interest and Profits*, Macmillan, 1899.
- Eugen von Boehm-Bawerk, *The Positive Theory of Capital*, 1889.
- Ludwig von Mises, "Capital Goods and Capital", from *Human Action*, and "Originary Interest", 1949.
- Ludwig von Mises, "Entrepreneurial Profit and Loss", from *Human Action*, 1949.
- Ludwig von Mises, "The Distinction Between Profits and Other Proceeds", from *Profit and Loss*, 1951.
- Ludwig von Mises, *Economic Calculation in the Socialist Commonwealth*, 1920.
- Murray N. Rothbard, "The Determination of the Pure Rate of Interest: The Time Market", from *Man, Economy, and State*, 1962.
- Murray N. Rothbard, "Justice and Property Rights: The Failure of Utilitarianism", 1974; reprinted in *The Logic of Action One*, 1997.
- Frederic Bastiat, "What Is Capital?", excerpted from *Capital and Interest*, 1849.
- Karl Marx, *Grundrisse: Foundations of the Critique of Political Economy*, manuscript 1857-58, trans. Martin Nicolaus, Penguin edition, 1973.
- Karl Marx, *Capital*, volume I, chapter 1, chapter 6, chapter 8 and chapter 15, 1867.
- Karl Marx, *Capital*, volume III, chapter 9, chapter 14 and chapter 38, 1894.
- Karl Marx, *Critique of the Gotha Programme*, 1875.
- Steve Keen, "Use-Value, Exchange-Value, and the Demise of Marx's Labor Theory of Value", *Journal of the History of Economic Thought* 15(1), 1993, pp. 107-121.
- Shalom Groll, "The Active Role of 'Use Value' in Marx's Economic Analysis", *History of Political Economy* 12(3), 1980, pp. 336-371.
- Avi J. Cohen and G. C. Harcourt, "Whatever Happened to the Cambridge Capital Theory Controversies?", *Journal of Economic Perspectives* 17(1), 2003.
- Piero Sraffa, *Production of Commodities by Means of Commodities: Prelude to a Critique of Economic Theory*, Cambridge University Press, 1960.
- Christopher J. Bliss, *Capital Theory and the Distribution of Income*, North-Holland, 1975.
- Kenneth J. Arrow and Gerard Debreu, "Existence of an Equilibrium for a Competitive Economy", *Econometrica* 22(3), 1954.
- Gerard Debreu, *Theory of Value: An Axiomatic Analysis of Economic Equilibrium*, Cowles Foundation Monograph 17, 1959.
- F. H. Hahn, "Revival of Political Economy: The Wrong Issues and the Wrong Argument", *Economic Record* 51(3), 1975.
- Frank Hahn, "The Neo-Ricardians", *Cambridge Journal of Economics* 6(4), 1982.
- Pierangelo Garegnani, "On a Change in the Notion of Equilibrium in Recent Work on Value and Distribution: A Comment on Samuelson", in Murray Brown, Kazuo Sato and Paul Zarembka (eds.), *Essays in Modern Capital Theory*, North-Holland, 1976, pp. 25-45.
- Pierangelo Garegnani, "On the Present State of the Capital Controversy", *Cambridge Journal of Economics* 36(6), 2012.
- Saverio M. Fratini, "On the Second Stage of the Cambridge Capital Controversy", *Journal of Economic Surveys* 33(4), 2019.
- Paul A. Samuelson, "A Summing Up", *Quarterly Journal of Economics* 80(4), 1966.
- David Levhari and Paul A. Samuelson, "The Nonswitching Theorem Is False", *Quarterly Journal of Economics* 80(4), 1966.
- Joan Robinson, "The Production Function and the Theory of Capital", *Review of Economic Studies* 21(2), 1953-54.
- Luigi L. Pasinetti, "Switches of Technique and the 'Rate of Return' in Capital Theory", *Economic Journal* 79(315), 1969.
- Aswath Damodaran, *Discounted Cash Flow Valuation*, NYU Stern lecture notes.
- Robert C. Merton, "On the Pricing of Corporate Debt: The Risk Structure of Interest Rates", *Journal of Finance* 29(2), 1974.
- William F. Sharpe, "Capital Asset Prices: A Theory of Market Equilibrium under Conditions of Risk", *Journal of Finance* 19(3), 1964.
- Joseph E. Stiglitz and Andrew Weiss, "Credit Rationing in Markets with Imperfect Information", *American Economic Review* 71(3), 1981.

- John R. Graham, Hyunseob Kim, Si Li and Jiaping Qiu, "Employee Costs of Corporate Bankruptcy", *Journal of Finance* 78(4), 2023.
- Oliver Hart and John Moore, "Property Rights and the Nature of the Firm", *Journal of Political Economy* 98(6), 1990.
- Companies Act 2006, section 3, section 544 and section 847; Insolvency Act 1986, section 74.
- Steve Keen, Robert U. Ayres and Russell Standish, "A Note on the Role of Energy in Production", *Ecological Economics* 157, 2019.
- George Tsatsaronis, "Definitions and Nomenclature in Exergy Analysis and Exergoeconomics", *Energy* 32(4), 2007.
- Robert U. Ayres and Benjamin Warr, "Accounting for Growth: The Role of Physical Work", *Structural Change and Economic Dynamics* 16(2), 2005.
- David J. Murphy et al., "Order from Chaos: A Preliminary Protocol for Determining the EROI of Fuels", *Sustainability* 3(10), 2011.
- US Energy Information Administration, "British Thermal Units (Btu)", *Energy Explained*.
- Jorge L. Hau and Bhavik R. Bakshi, "Expanding Exergy Analysis to Account for Ecosystem Products and Services", *Environmental Science & Technology* 38(13), 2004.
- David M. Paulus Jr. and George Tsatsaronis, "Auxiliary Equations for the Determination of Specific Exergy Revenues", *Energy* 31(15), 2006.
- United Nations et al., *System of Environmental-Economic Accounting 2012 - Central Framework*, 2014.
- Pierre-Joseph Proudhon, *What Is Property?*, 1840.