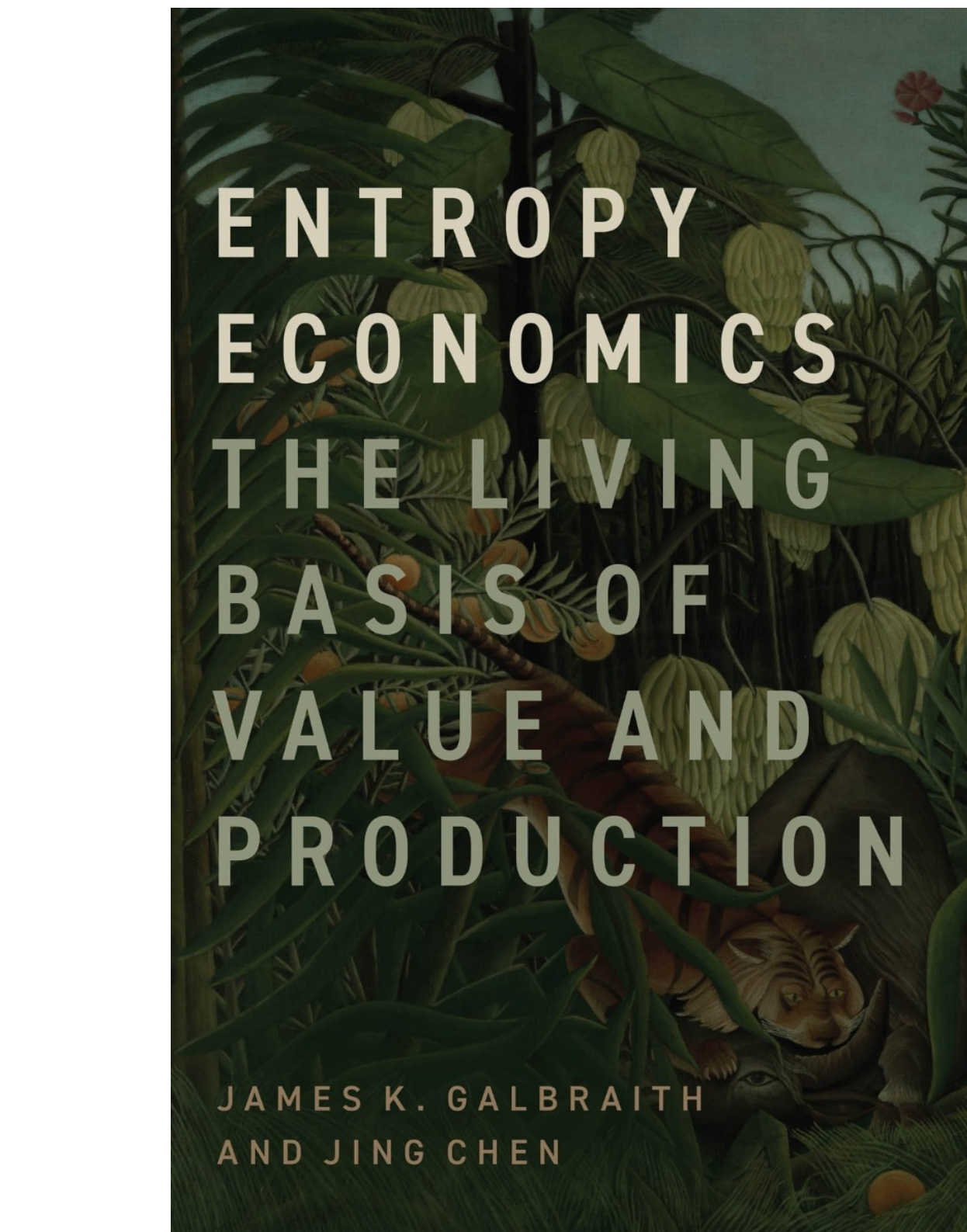


# Entropy Economics

What it is and why it matters

A presentation by  
James K. Galbraith

LBJ School PhD Sack Lunch Seminar  
February 26, 2026

The book cover features a detailed illustration of a tiger in a lush jungle. The tiger is positioned in the lower half of the frame, looking towards the viewer. The background is filled with dense green foliage, including large leaves and hanging seed pods. The overall color palette is dominated by various shades of green and brown, creating a naturalistic and somewhat somber atmosphere.

# ENTROPY ECONOMICS THE LIVING BASIS OF VALUE AND PRODUCTION

JAMES K. GALBRAITH  
AND JING CHEN

Based on a book published by  
The University of Chicago Press  
in January, 2025

Jing Chen was trained as a mathematician in China, emigrated to Canada in 1989 and presently teaches Finance at the University of Northern British Columbia. We have worked together for over 15 years, with articles in the *Cambridge Journal of Economics* (2012), the *Journal of Economic Issues* (2011, 2012) and in the *Review of Evolutionary Political Economy* (2023, 2024).

# Theories of Value in Economics

- Theories of value are foundational in economics but like most foundations, they aren't visible most of the time.
- Foundations become visible when they start to crumble, or when they collapse.
- They tend to crumble, or even collapse, when they have been neglected, and taken for granted, for too long.
- This is a basic principle of... entropy.



# In Classical Economics



- From Smith to Ricardo to Marx to J.S. Mill, economics developed a theory of value based on labor embodied in production, what Marx called “socially necessary labor time.”
- This theory dealt with the value of goods that could be produced and reproduced; it was an objective theory, based on a search for an *invariable standard of value*.
- Around 1870, Mill declared the theory to be complete; whereupon it collapsed.

(Though not entirely, but that's another story.)





# In Neo-classical Economics

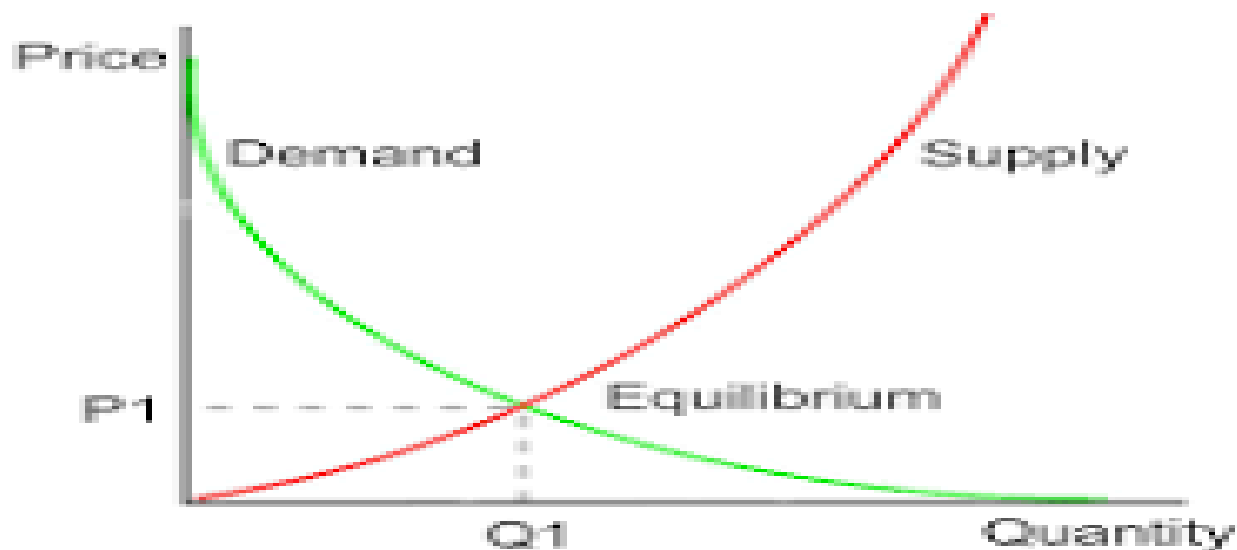
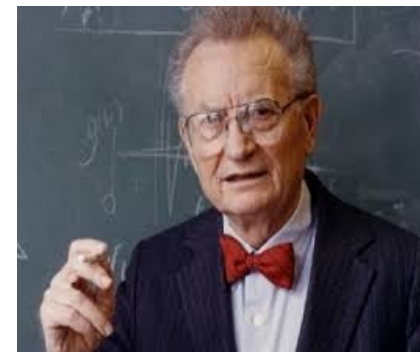


- From Jevons to Marshall to Samuelson, economics developed a theory of value based on utility, more precisely, marginal utility.
- The theory deals mainly with goods that exist: the “allocation of scarce resources.” It is a subjective theory of value in equilibrium.
- Around 1950, the theory achieved its highest expression, by Arrow and Debreu. E. Roy Weintraub described their work as a “very well-arranged cemetery with...beautiful tombstones.”

(Everyone knows that the conditions for this theory to work are impossible, but that has not prevented it from enduring as the foundation of mainstream economics)



# In Textbook Economics



---

In your standard text, value is conflated into a theory of price, based on the “ideal” conditions of perfect competition, perfect information, rational behavior and so forth, leading to equilibrium where markets clear at a given Price. This framework is then replicated over many problems, large and small. Time does not appear in the model; the equilibrium is timeless, whatever that is supposed to mean. Sraffa condemned this theory in the 1920s, no luck.



# Keynes's Complaint

About the Supply Curve in (Neo-)classical Economics

“The classical theorists resemble Euclidean geometers in a non-Euclidean world who, discovering that in experience straight lines apparently parallel often meet, rebuke the lines for not keeping straight – as the only remedy for the unfortunate collisions which are occurring. Yet, in truth, there is no remedy except to throw over the axiom of parallels and to work out a non-Euclidean geometry. Something similar is required to-day in economics.”



Drawings  
By  
David Low

The General Theory of Employment Interest and Money, Ch. 2.



# In Keynes's Economics



- John Maynard Keynes, drawing on Freud and Einstein (“*The General Theory of....*”) and his own background as a student of Moore and Russell, implicitly urged a social concept of value rooted in beauty, art, peace, well-being.
- “Keynesian” economics rather vulgarly dissolved those ideas into the growth of economic output: an (undeclared) “Gross Domestic Product theory of value.” It is objective, but it abandons any attempt to ascribe value to specific goods or services, apart from market price.

# The Search Goes On...



## *A Labour Theory of Value*

Luigi L. Pasinetti

December 2024

In a beautiful book to be published posthumously this year, the late Luigi Pasinetti restates the labor theory of value, elegantly based on Marx, Sraffa and his own work over many years. That Pasinetti should devote over 550 pages to this topic late in his life underscores that the theory of value is not yet a settled topic in economics.

# What is the Entropy Law?

- The great achievement of late-19<sup>th</sup> century science was the articulation, by Joule and others, of the Second Law of Thermodynamics – the proposition that heat always moves away from the hotter body and that disorder has a tendency to increase.
- *Entropy* captures this tendency. It was given mathematical expression in information theory, developed by Claude Shannon in 1948, the basis of modern computer science.

# Early Thermodynamics



A thermal calorimeter, to measure the heat content of food, in the laboratory of its inventor, W.O. Atwater, late 19<sup>th</sup> century.

W.O. Atwater, famous among other things for establishing that alcohol has food value. Also my maternal great-grandfather.



# Grave of W.O. Atwater



Indian Hill Cemetery, Middletown Connecticut, July 2025.

# Entropy in Economics?

- We now understand the entropy law to be the most basic law of nature. It underpins physics, biology, mechanical systems.
- But in mainstream economics, market processes are supposed to allocate scarce resources to their best uses, replicating in equilibrium, unless “shocked.”
- As a result, when things change, or decay, economics as such has nothing to say about it! “No-one could have foreseen” the Great Financial Crisis, just for instance.



# Samuelson Warned: Don't Go There!

There is really nothing more pathetic than to have an economist or a retired engineer try to force analogies between the concepts of physics and the concepts of economics. How many dreary papers have I had to referee in which the author is looking for something that corresponds to entropy or to one or another form of energy. (Samuelson 1970, 7)

In the very next paragraph, however, Samuelson found an analogy himself: “Pressure and volume, and for that matter absolute temperature and entropy, have to each other the same conjugate or dualistic relation that the wage rate has to labor or the land rent has to acres of land” (Samuelson 1970, 7).

Philip Mirowski observed, “The key to the comprehension of Samuelson’s meteoric rise in the economics profession was his knack for evoking all the outward trapping and ornament of science without ever coming to grips with the actual content or implications of physical theory for his neoclassical economics” (Mirowski 1989, 383).

Hmm....



# Can Entropy Underpin Value?

- In 1971, Nicolas Georgescu-Roegen published *The Entropy Law and the Economic Process*.
- NGR suggested that economics could be reconstructed around the entropy law, but thought it too difficult to relate entropy to prices of production.
- We, on the other hand, think this is a problem that can be solved and that the solution is both very easy and very fruitful.

# An Entropy Theory of Value

Economic value depends on scarcity and on the degree of market power or monopoly. Scarcity can be represented as a probability. New products are inherently scarce but become less so with time; value is therefore an evolving, non-equilibrium construct. Monopoly can be modeled by the base of the log function, just as Shannon used base 2 for his measure of information. We vary the base according to the number of suppliers.

$$V(P) = -\log_b P$$

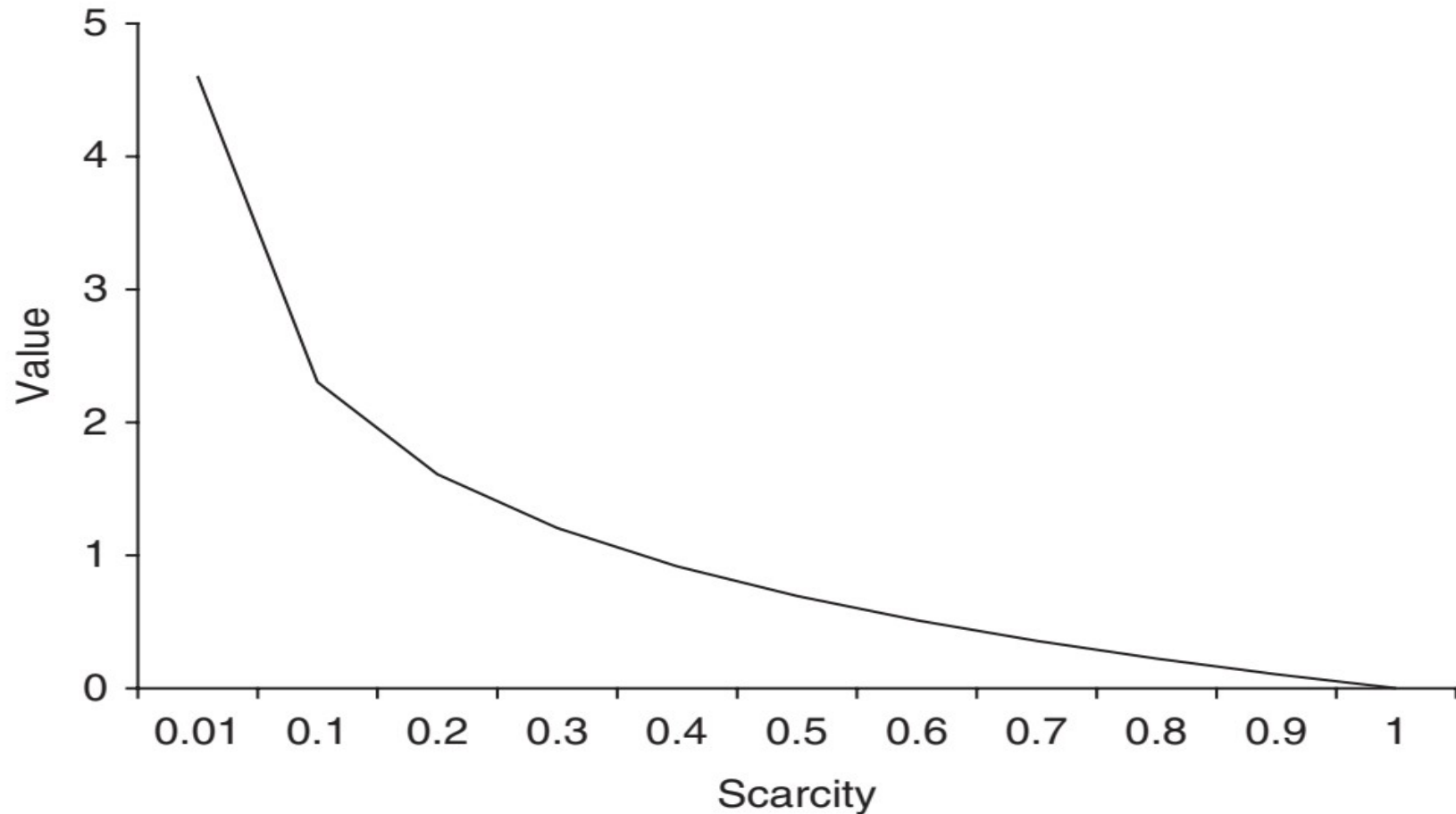
Adding across products or processes, one can measure the value of a collection of goods and services; the equation is identical to the entropy measure in physics and information theory. As in information theory, it is a lower bound, objective measure.

$$V(X) = \sum_{i=1}^n P_i (-\log_b P_i)$$

Also notice the similarity to Henri Theil's measure of inequality, also derived from Shannon.

# Scarcity and Value

An economic good or service loses value as it becomes more widely-diffused. This is why all new production seeks to provide a distinctive, “new” product or service. (There is almost no such thing as a generic commodity.)



**FIGURE 4.1** Value and scarcity.

This relation also explains why new “tech” companies have high stock valuations while mature industrial firms, though much larger, generally do not.

# Market Power and Economic Value

Monopoly or oligopoly is a highly-desired way to extract economic value  
However the power conveyed declines quickly as the number of suppliers  
Increases.

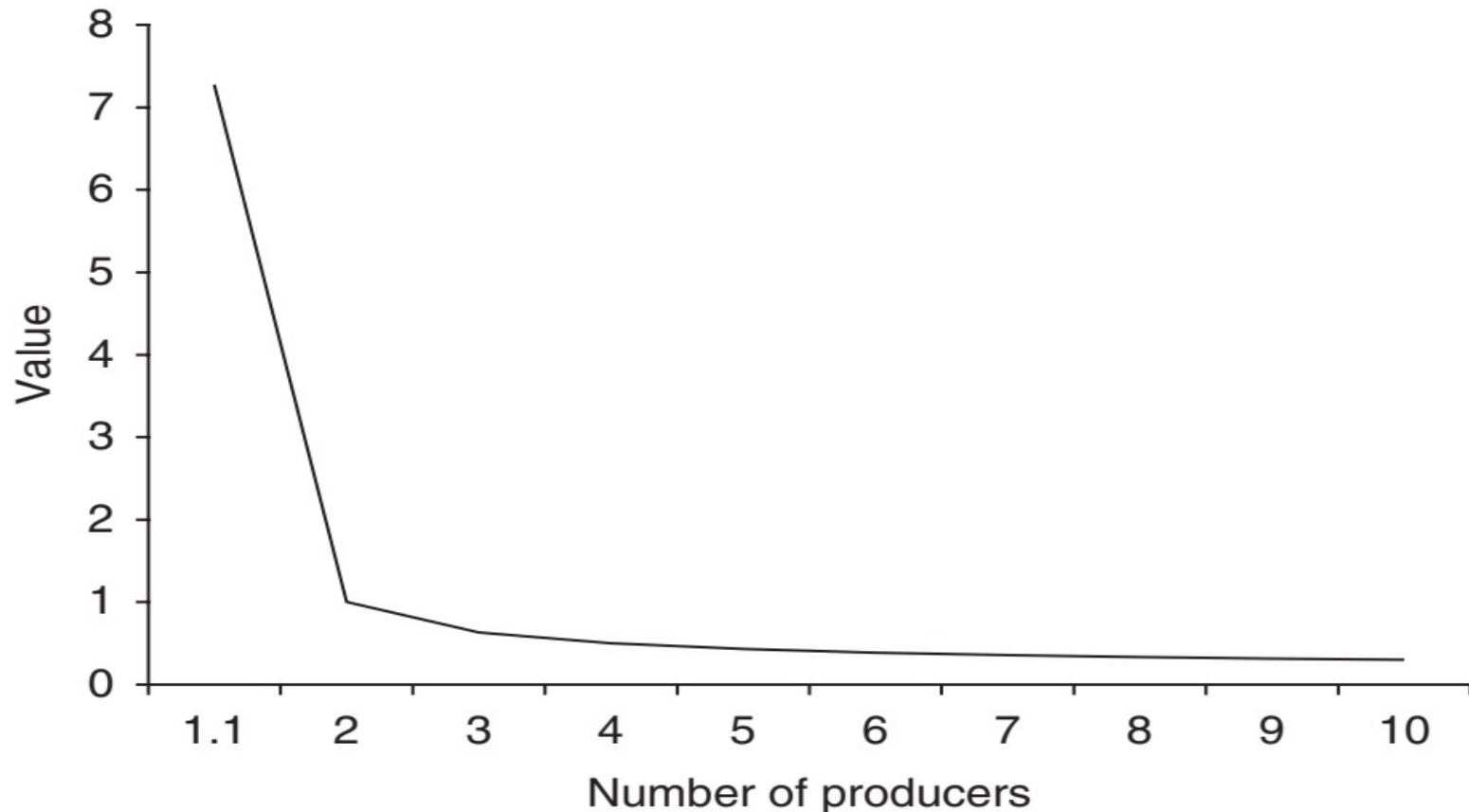


FIGURE 4.2 Value and the number of producers.

# Key Role of Resources

- High quality resources, when abundant, have low economic value, but they are the foundation of activities that generate economic value
- Food, energy, rare earths are examples
- Energy and rare earths feed a system that generates new technologies, products and weapons, which are scarce and valuable.
- Control of resource-producing regions is a key to the wealth of those that do not have high-quality resources.

# Example of Critical Minerals

- China controls the refining of rare earths (which are not themselves actually rare) and the production of gallium, a by-product of refining bauxite into alumina. Gallium is indispensable for advanced (military-use) micro-electronics.
- China's advantage in alumina over the US is about 90 million metric tons/year to 1 mmt/yr.
- Monopoly power over this key resource gives China the ability to specify the terms of trade and other policy – including security policy – to the United States.
- Realization of this fact (a bit tardy...) is what produced a trade truce between the US and China in 2025.



# Example of Russian Gas and Oil

- Sanctions on Russian gas and the destruction of Nordstream were based on the idea that Russia needs “hard” currency to finance war. However higher prices offset falling volumes
- In resource terms, sanctions reduced the quantity and raised the value of gas and oil in Europe, undermining the profitability of European business.
- In Russia, the reverse effect: prices were stable and profitability rose. (Sanctions were a gift.)





# Example of Armaments Trade

- Armaments are typically thought of as being specific to the country that produces them and an instrument of national power.
- That is because there is (in the standard view) only one buyer and several or many producers.
- However, in the modern West – NATO – firms differentiate their weapons and export to many buyers. This reverses the power relationship, passing power to the contractors.
- In Russia, weapons are standardized, of low economic value, but cheap and abundant.

# Example of Market Integration

(e.g., United States and Venezuela)

TABLE 4.1. Summary of value changes with market integration

	Segmented market		Integrated market
	 Resource-poor region	Resource-rich region	
Market size	1,000	100	1,100
Scarcity	0.2	0.9	0.26
Unit price	1.61	0.11	1.33
Value in segregation	321.89	9.48	331.37 (sum in segregation)
Value in integration	266.64	120	386.62
Difference in value	-55.25	110.51	55.25

Integrating a resource-rich (V) and resource-poor (US) region brings gains to resource producers in the resource-rich region (V) and to consumers in the resource-poor (US) region. But consumers in the resource-rich region (V) and producers in the resource-poor (US) region will be unhappy.

The question of who controls production in the resource-rich region is therefore decisive.

The theory is consistent with the idea that the USG wants US producers to control Venezuela.

# That's it! Moving on...

- Our proposed theory of value is extremely simple, mathematically transparent.
- It is an analytical theory: you can plug in numbers and derive predictions for real-world situations.
- It is a non-equilibrium theory, since  $P$  (the probability measure) is always changing, generally increasing as time passes, unless there is an increase in the potential market.
- Or, if you like, “Equilibrium” = “Maximum Entropy” = Death

# Theories of Production

- Classical theory of production was basically about the application of labor to land and raw materials, the creation of net product, and the role of exploitation (surplus value).
- Neoclassical theory of production is basically about “factor markets” – labor and capital – and subsumes production into the model of exchange. Nothing changes in the production process; the main point of the theory is an analysis of returns to the factors (wages, profits).

# Neoclassical Production

The Cobb-Douglas function takes the form

$$Y = AK^\alpha L^{1-\alpha}$$

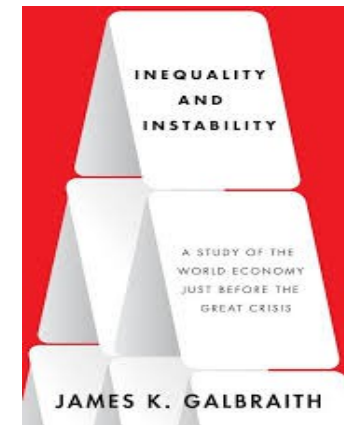
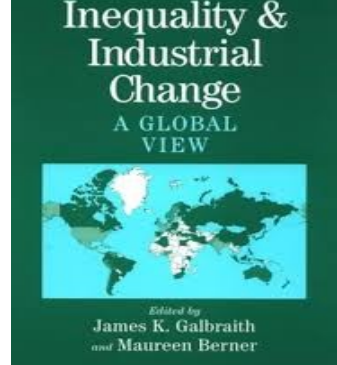
where  $Y$ ,  $L$ , and  $K$  denote output, labor (variable cost), and capital (fixed cost), respectively. Since  $\alpha$  and  $(1 - \alpha)$  sum to 1, the Cobb-Douglas function (in this form) exhibits constant returns. If we sub-

TABLE 5.1. Outputs of the Cobb-Douglas function under varying coefficients and K/L ratios

Capital	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
Alpha									
0.1	1.44	1.39	1.29	1.15	1.00	0.83	0.65	0.46	0.25
0.2	1.16	1.21	1.18	1.11	1.00	0.87	0.71	0.53	0.31
0.3	0.93	1.06	1.09	1.06	1.00	0.90	0.77	0.61	0.39
0.4	0.75	0.92	1.00	1.02	1.00	0.94	0.84	0.70	0.48
0.5	0.60	0.80	0.92	0.98	1.00	0.98	0.92	0.80	0.60
0.6	0.48	0.70	0.84	0.94	1.00	1.02	1.00	0.92	0.75
0.7	0.39	0.61	0.77	0.90	1.00	1.06	1.09	1.06	0.93
0.8	0.31	0.53	0.71	0.87	1.00	1.11	1.18	1.21	1.16
0.9	0.25	0.46	0.65	0.83	1.00	1.15	1.29	1.39	1.44

In short and without wasting time, Cobb-Douglas maximizes output when production is all labor or all capital. This is not the real world.

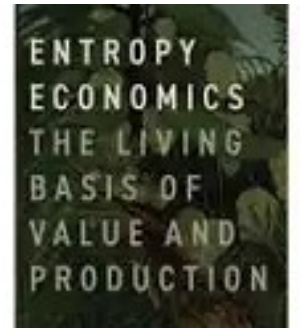
# Real-World Principles



- All organized activity is based on prior investment (plant, animal, economic, social)
- All organizations (cells, firms, countries) have boundaries, and are built according to plans (DNA, blueprints, habits, laws, regulations)
- Inequalities (temperature, pressure, income, wealth) motivate all useful work.
- But if inequalities are too large, they are destructive. Inequalities must be controlled.
- Therefore regulation is essential, and all regulation is about controlling inequalities.

# Entropy Theory of Production

- Production is the central economic activity
- All production requires low-entropy resources
- Which must be extracted with a surplus
- To do this, requires fixed investment
- Which is carried out according to a plan.
- More complex systems are more efficient, but more fragile. They must be maintained.
- There is no equilibrium in real life, except at “maximum entropy”, which is death.
- Nothing lasts forever!



# Mathematics of Production

- Our theory of production is very similar to that of Keynes: the problem is to model a decision to produce, based on the available technologies, fixed and variable costs, uncertainty, discount rates, and project duration.
- The relevant expression resembles the Black-Scholes formula in finance, with a difference of sign. Theirs is a backward-looking thermodynamic equation, ours is forward-looking. The two equations solve different economic problems.

# Production Dynamics

$$C = SN(d_1) - Ke^{-rT} N(d_2) \quad (10)$$

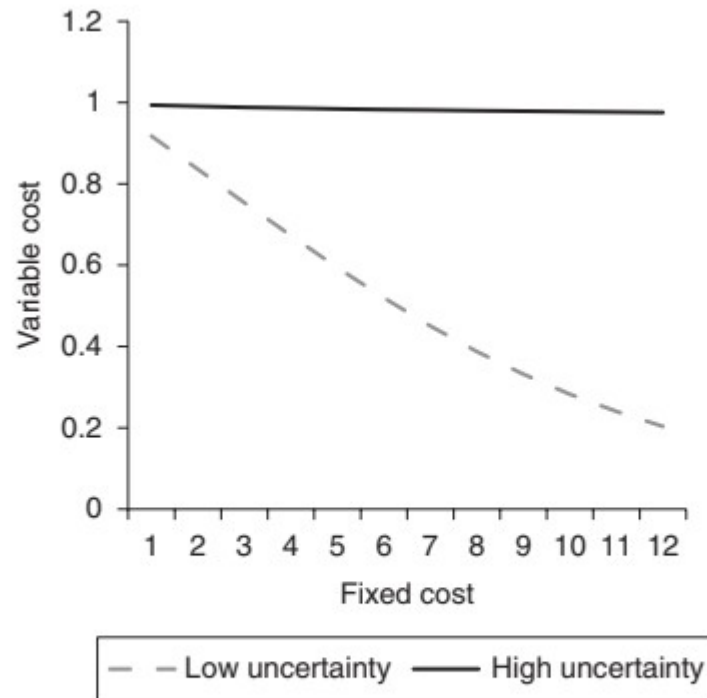
where

$$d_1 = \frac{\ln\left(\frac{S}{K}\right) + \left(r + \frac{\sigma^2}{2}\right)T}{\sigma\sqrt{T}}$$
$$d_2 = \frac{\ln\left(\frac{S}{K}\right) + \left(r - \frac{\sigma^2}{2}\right)T}{\sigma\sqrt{T}} = d_1 - \sigma\sqrt{T}$$

Formula (10) provides an analytical expression for  $C$ , variable cost, as a function of  $S$ , product value, for  $K$ , fixed cost, for  $\sigma$ , uncertainty, for  $T$ , duration of project, and for  $r$ , the discount rate of a firm. As in physics, the calculated variable cost is the average expected cost of the variable inputs. With this formula, we can calculate how variable cost changes with respect to other major factors in economic and biological activities. Formula (10) takes the same form as the Black-Scholes formula for European call options. But the meaning of parameters in this theory differs from those in option theory.

(N, in case you are wondering, is the cumulative distribution function of a standard normal variable.)

# Some Implications



**FIGURE 7.1** Fixed cost and uncertainty: In a low-uncertainty environment, variable cost drops sharply as fixed costs are increased. In a high-uncertainty environment, variable costs change little with the level of fixed cost.

Low – uncertainty environments favor investments with high fixed costs

# More Implications

160 CHAPTER 7

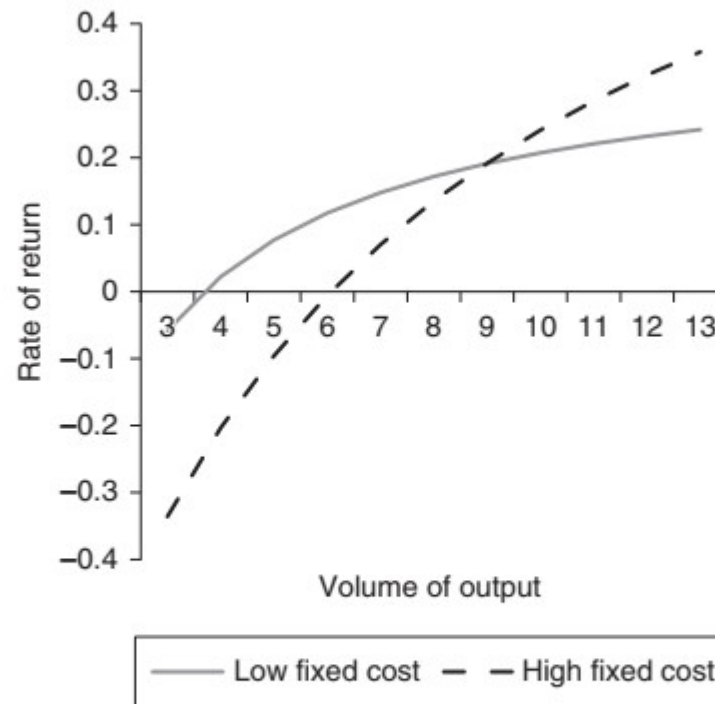


FIGURE 7.2 Fixed cost and the volume of output: For a high-fixed-cost investment, the break-even market size is higher and the return curve is steeper. The opposite is true for a low-fixed-cost investment.

With high fixed costs, you need a larger output to break even. But it is more profitable at higher levels of output.

# Another Implication

*A Biophysical Theory of Production in Mathematical Form* 163

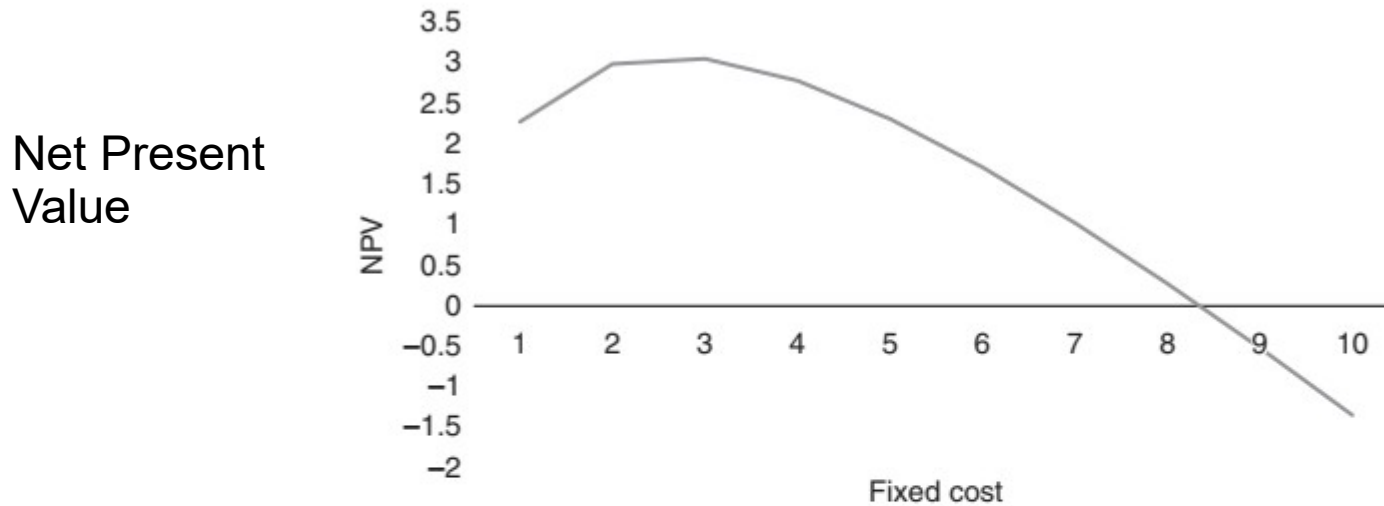


FIGURE 7.3 Fixed cost and returns.

When the level of fixed cost is at a certain level, its further increase will reduce the value of the project. Eventually the value of the project will become negative. Education is a type of fixed cost in our lives. We generally regard education as a worthwhile investment. But most people, for good reason, will not pursue PhD degrees.

After a certain point, even pursuing a PhD becomes an unprofitable proposition. (Sorry to break the news on that one...)

# Uncertainty is a Buzz-Kill

TABLE 7.3. Discount rates, investment, uncertainty, and rates of return

	Initial expectation		Sad result	
Discount rate	0.03	0.1	0.03	0.1
Annual output	1	1	1	1
Fixed cost	7.1	3.9	7.1	3.9
Duration of project	35.7	13.6	35.7	13.6
Uncertainty	0.3	0.3	0.8	0.8
Variable cost	0.46	0.42	0.97	0.86
<b>NPV</b>	<b>12.3</b>	<b>4.0</b>	<b>-6.2</b>	<b>-2.0</b>

If you set out with confidence on a project, with a low discount rate and make a big investment in the hope of a big return, and the uncertainty *ex post* is much higher than you expected, you will suffer a much bigger loss than if you took a more conservative approach at the beginning.

# Stability is Destabilizing

TABLE 7.4. Stability is destabilizing

Uncertainty	0.3	0.55	0.8	0.8
Annual output	1	1	1	1
Fixed cost	5.8	2.1	5.8	2.1
Discount rate	0.05	0.05	0.05	0.05
Duration of project	25.3	12.1	25.3	12.1
Variable cost	0.44	0.64	0.94	0.82
NPV	8.5	2.3	-4.4	0.0

Low Uncertainty fosters investment in high-fixed cost projects even where discount rates are the same. But if the uncertainty level goes up (for example, as the result of a financial crisis) the NPV of the project built with expectation of low uncertainty will fall much more.

# No surprises, really.

- None of the above (and many more examples in the book) are intuitively surprising – the argument is easily recognized by anyone with business or financial experience.
- The virtue of our case is that each of these observations flows from the mathematical argument, which in turn...
- ...flows from application of the second law of thermodynamics – the entropy law.

# An interpretation of the Depression

- Our theory of value and production lends an underpinning to the hypothesis, offered by Chris Kennedy of the University of Victoria to the UT Energy Symposium last October, that the announcement of massive oil discoveries in Texas in late 1929 precipitated the Great Crash and the Great Depression.
- Railroad stocks collapsed, as did the horse-based agricultural economy. It took the New Deal to lay down the infrastructure required for the new sources of energy (oil and hydro).

# Coincidence? Or Cause and Effect?

*New York Times, Oct. 22, 1929*

## **STANDARD OIL CUTS CALIFORNIA PRICES**

**Reduction of 50 to 75 Cents a  
Barrel Attributed to Big  
Overproduction.**

### **OTHERS TO FALL IN LINE**

**Shell Company Announces It Will  
Meet New Rates—Union Oil  
Expected to Act Also.**

37

*New York Times, Oct. 24, 1929  
(Black Thursday)*

## **PRICES OF STOCKS CRASH IN HEAVY LIQUIDATION; TOTAL DROP OF BILLIONS**

**PAPER LOSS \$4,000,000,000**

**2,600,000 Shares Sold  
in the Final Hour in  
Record Decline.**

**MANY ACCOUNTS WIPED OUT**

39

*New York Times, Oct. 29, 1929*

## **STANDARD OIL CUTS BIG CRUDE STORAGE**

**New Jersey Company Announces  
Reduction of 20,000,000 Bar-  
rels, or 22%, in 2½ Years.**

### **REVERSES PREVIOUS POLICY**

**Future Held No Longer Uncertain  
and Utilization of Stocks  
Financially Desirable.**

**Holding that the future supply of  
crude oil was no longer an uncer-  
tainty, the Standard Oil Company of  
New Jersey yesterday announced a  
reversal of the long established pol-  
icy of storage of crude oil against a  
possible shortage. The announce-**

40

*New York Times, Oct. 29, 1929  
(Black Tuesday)*

## **STOCK PRICES SLUMP \$14,000,000,000 IN NATION-WIDE STAMPEDE TO UNLOAD; BANKERS TO SUPPORT MARKET TODAY**

Source: Chris Kennedy, Univ of Victoria

# Current Implications

- Despite its simplicity, our theory underpins a world-view with many current practical applications, that would permit economists to address key policy questions in a realistic way.
- Among these are matters relating to national and international security (sanctions), trade, new technologies for energy production (solar) and use (AI), and household economics, affecting reproduction and the demographic future.
- Again, no surprise: a universal law has many uses and implications.

Thank you for your attention to this matter!

