Analysis of Technology as a Fifth Factor of Production

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ABSTRACT

For most of the history of economic thought, the factors of production have been listed as land, labour, capital and entrepreneurship. The spread of digital technology, from cloud computing to data-driven systems and artificial intelligence (AI), puts that list under pressure. This paper asks whether technology now deserves to be counted as a fifth factor in its own right, separate from physical capital. I draw on endogenous growth theory, the idea of non-rivalrous goods and the pattern of increasing returns to scale to argue that technology has economic properties the other four factors lack. A case study of Amazon's fulfilment and data centre operations shows how technology augments, replaces and reshapes the traditional factors. The paper then turns to the problem of measuring technology in national accounts, sets out policy reforms for the digital economy, and considers what a fifth factor would mean for labour markets, competition policy and development. My conclusion is that technology is more than an enabler. It is the architecture that modern production runs on, and economic theory and practice should account for it formally.

KEYWORDS

Technology, factors of production, endogenous growth, non-rivalry, increasing returns, intangible capital, national accounts

I. INTRODUCTION

Economics students learn four factors of production: land, labour, capital and entrepreneurship. Together they have long explained how goods and services are produced, distributed and consumed. Land supplies natural resources and physical space. Labour brings human effort and skill. Capital provides machines, tools and infrastructure. Entrepreneurship organizes the other three and carries the risk of putting them together. The scheme goes back to Adam Smith (1776) and David Ricardo (1817), was refined by the neoclassical economists, and has anchored economic analysis for more than two centuries.

The economy of the twenty-first century looks very little like the industrial economy that produced this framework. In 2026 the most valuable companies in the world (Apple, Nvidia, Microsoft, Alphabet and Amazon) earn their market value mainly from intangible assets such as algorithms, software platforms, data networks and AI systems. Their physical assets are small next to those of the industrial giants of the mid-twentieth century. One software update can improve millions of devices at once. An AI model gets better with each interaction. A digital platform can connect billions of users without becoming any less useful to them.

This gap between classical theory and what we see today raises a basic question: has a new factor of production emerged?

Technology is the obvious candidate. This paper examines it systematically as a possible fifth factor of production.

A. Three research questions guide the analysis:

- Does technology have economic characteristics that set it apart from the traditional four factors?
- How does technology interact with, and change, land, labour, capital and entrepreneurship?
- What are the measurement, policy and distributional implications of recognizing technology as a fifth factor?

The rest of the paper is organized as follows. Section two reviews how factor theory developed and how economists have argued about technological change. Section three sets out a theoretical framework for treating technology as a distinct factor, including its defining characteristics and a reformulated production function. Section four tests the argument against a case study of Amazon. Section five takes up the problem of measuring technology in national accounts, and section six looks at the policy implications. Section seven discusses limitations and directions for future research, and section eight concludes.

II. LITERATURE REVIEW

A. The Classical Tradition

Factor theory begins with classical political economy. Adam Smith (1776) named three factors: labour, capital and land. He saw labour as the main source of value, with capital and land as necessary inputs. David Ricardo (1817) built on this, stressing that land is subject to diminishing returns and examining how output is shared among landowners, capitalists and workers.

Neoclassical economists later formalized the framework and developed the marginal productivity theory of distribution, in which each factor is paid according to what it adds to output. The production function, a mathematical statement of how inputs turn into outputs, became the main tool for studying growth and productivity.

B. The Neoclassical Treatment of Technology

Neoclassical growth theory gave technology an awkward role. Robert Solow (1956, 1957) showed that growth in labour and capital inputs could not account for all of the growth in output. The leftover became known as the "Solow Residual". It was usually read as technological progress and treated as an exogenous force that pushed the production function upward over time.

For Solow and his followers, technology was not a factor of production in its own right. It was a measure of how efficiently the existing factors were combined. A factory with advanced machinery produces more than one with simple tools, but neoclassical analysis would credit that to the quality of the capital, not to a separate technological factor.

This view of technology as "embedded capital" is still common in mainstream economics, and it has some logic. When technology is built into physical machinery, the line between it and capital blurs. A computer and a typewriter are both capital; they differ only in sophistication.

C. The Endogenous Growth Revolution

By the 1980s and 1990s the limits of this approach were hard to ignore. Paul Romer (1986, 1990) and Robert Lucas (1988) developed endogenous growth theory, which starts from the observation that technological change does not arrive from outside the economy. It results from deliberate choices: investment in research and development, innovation and human capital.

Romer (1990) made an especially important point about the non-rivalrous nature of technological knowledge. A piece of physical capital can be used by only one firm at a time, but knowledge can be copied and used by many firms at once. Because of this, technology shows increasing returns to scale, unlike the traditional factors, which show diminishing returns.

Endogenous growth theory gave technology a firmer footing than a residual. Even so, it usually treated technology as a public good or an externality, not as a factor with its own supply and demand.

D. Schumpeter and Creative Destruction

Joseph Schumpeter (1942) offered a different angle. He put innovation and entrepreneurship at the centre of economic development, and he described "creative destruction" as the continuing process in which new technologies displace old ones, create new industries and make others obsolete.

Schumpeter's framework shows how dynamic and disruptive technological change is. Technology here is an active force that reshapes the structure of the economy, not a passive input. That fits the argument of this paper, that technology deserves recognition as an independent factor of production.

E. Contemporary Perspectives

More recent work has started to deal with what digital technology means for economic theory. Brynjolfsson and McAfee (2014) argue that we have entered a "Second Machine Age", in which digital technologies, especially AI and machine learning, are changing the nature of work and production. They point out that digital goods can be reproduced at close to zero marginal cost, which changes the economics of production at its root.

Author, Levy and Murnane (2003) and later task-based models of production look at how technology replaces labour in routine tasks while complementing it in non-routine, cognitive ones. This work shows that technology does more than augment labour. It changes the mix of tasks that employers demand.

Aghion, Jones and Jones (2018) develop models of "AI-augmented growth" to study what AI might do to long-run growth. They find that bringing AI into production could raise growth rates for a sustained period, but only if the particular properties of AI as a factor are properly understood.

III. THEORETICAL FRAMEWORK

A. Technology as a Fifth Factor

1. Defining Technology as a Factor

For technology to count as a fifth factor, we first need to say what it is. In this paper, technology means "the codified knowledge, digital infrastructure, algorithms and data systems that enable, augment and transform the production of goods and services".

Table 1: The definition has four components:

Component	Description	Examples
Codified Knowledge	Scientific understanding, technical specifications, and proprietary information captured in patents, manuals, and software code	Chemical formulas, engineering blueprints, proprietary algorithms
Digital Infrastructure	The physical and virtual networks that enable data storage, processing, and transmission	Cloud computing platforms, 5G networks, data centres
Algorithms & AI	Decision-making systems, optimization routines, and machine learning models	Recommender systems, autonomous vehicles, generative AI
Data	Structured and unstructured information that serves as input to algorithms and decision-making	Consumer behaviour data, sensor readings, training datasets

B. The Distinctive Characteristics of Technology

If technology is a distinct factor, it should have characteristics the traditional four factors do not. Table 1 compares them side by side.

Table 2: Comparative Characteristics of Factors of Production

Characteristic	Land (N)	Labour (L)	Capital (K)	Entrepreneurship (E)	Technology (T)
Rivalrous	Yes	Yes	Yes	Limited	No
Subject to Diminishing Returns	Yes	Yes	Yes	Yes	No (Increasing Returns)
Depreciates with Use	Yes (depletion)	Yes (fatigue)	Yes (wear)	Yes (burnout)	No (Improves with Use)
Marginal Cost of Replication	High	High	High	High	Near Zero
Excludability	High	High	High	High	Low to Moderate
Storability	Yes	No (time-bound)	Yes	Yes	Yes
Transferability	Limited	Limited	High	Limited	High

1. Non-Rivalry

The most basic feature of technology is that it is non-rivalrous. A tractor (capital) can work only one field at a time, and a worker can be in only one place. A software algorithm, by contrast, can be used by thousands of firms on millions of devices at once without losing any of its usefulness. It can be reused indefinitely at almost no extra cost.

Romer (1990) saw this as the key difference between ideas and objects. Technology, as codified knowledge and algorithms, belongs with ideas, and its non-rivalry is what makes increasing returns to scale possible in technology-intensive industries.

2. Increasing Returns

Since technology is non-rivalrous, it shows increasing returns to scale. Take a large language model. The first copy takes heavy investment in research, computing power and training data. After that, the model can be offered to millions of users for very little extra. It also improves with use, because every interaction produces data that can be used to refine it. The traditional factors behave differently. Land, labour and capital all show diminishing returns: add more land, more workers or more machines and each addition eventually brings smaller gains in output. Technology runs the other way, and its value grows with scale and use.

3. Improvement with Use

Technology also improves with use. Search is the classic example: Google's search engine gets better with every query, because user behaviour data helps refine its ranking algorithms. Machine learning models likewise improve as they process more data. Physical capital goes the other way and depreciates with use. A machine wears down and a worker tires. Software-based technology tends to get better the more it is used.

4. Near -Zero Marginal Cost of Replication

Digital technology can be copied at almost no marginal cost. Once an application has been developed, one more copy costs next to nothing. Physical goods are different, since every extra unit needs rawer materials, labour and energy.

This matters for pricing, market structure and growth. Technology-intensive goods can be sold very cheaply, which can create large consumer surplus. It also pushes markets toward natural monopoly, because a firm with a large-scale technology can undercut rivals who face higher marginal costs.

C. The Augmented Production Function

With these characteristics established, the production function can be reformulated to include technology as a fifth factor.

Classical Production Function:

$Q = f(L, K, N, E)$

Where Q = Output, L = Labour, K = Capital, N = Land/Natural Resources, E = Entrepreneurship

Augmented Production Function:

$Q = T \bullet f(L, K, N, E)$

Here T stands for the stock of technological capital. This version treats technology as a multiplier that raises the productivity of all the traditional factors.

This form may still understate what technology does. A fuller version would let technology change the productivity of each factor:

$Q = f(T, L(T), K(T), N(T), E(T))$

Now the productivity of labour, capital, land and entrepreneurship is itself a function of technology. Technology does not just sit beside the traditional factors; it permeates them. A worker with AI assistance (T) is more productive than one without. A machine with predictive maintenance software (T) outperforms one without it. Land farmed with precision agriculture (T) yields more per acre.

D. Technology as a Meta-Factor

Taken together, this suggests that technology is best understood as a meta-factor, one that augments and transforms the productivity of all the other factors. Figure 1 illustrates the idea. In this framework technology is the architecture on which the traditional factors operate, and it sets the productivity ceiling for the economy as a whole.

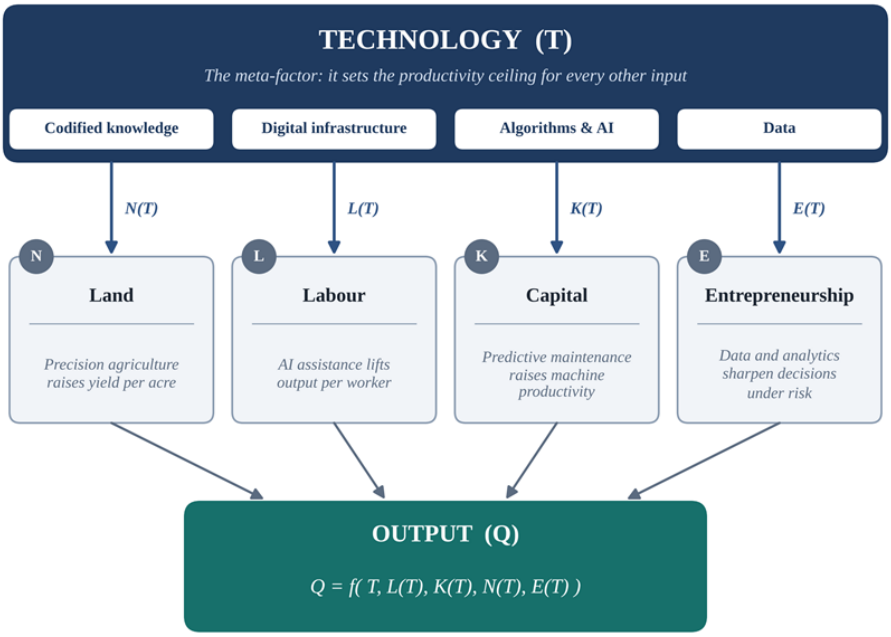


Figure 1: Technology as the Meta-Factor of Production

IV. EMPIRICAL EVIDENCE: CASE STUDY OF AMAZON

To ground the theory in evidence, this section looks at Amazon.com Inc., a firm whose competitive advantage clearly comes from technology as a factor of production.

A. Amazon: Beyond Retail

Amazon started in 1995 as an online bookstore and has grown into one of the most technologically advanced companies in the world. It operates across e-commerce, cloud computing, logistics, digital content and AI. People often call it a retailer, but its main assets are technological, not physical.

B. Traditional Factors at Amazon

Table 3: A traditional analysis of Amazon's operations would identify:

Factor	Amazon's Traditional Assets
Land (N)	Warehouses, fulfilment centres, and physical store locations
Labour (L)	Warehouse workers, delivery drivers, customer service representatives
Capital (K)	Conveyor belts, robotic systems, delivery vehicles
Entrepreneurship (E)	Jeff Bezos's vision, organizational structure, risk-taking culture

Yet these four factors alone do not explain Amazon's dominant market position or its extraordinary growth.

C. Technology as the Fifth Factor at Amazon

Amazon's real advantage lies in its technological assets, which include the following.

1. Kiva Robotics Systems

Amazon bought Kiva Systems in 2012 and put its robots to work in fulfilment centres. The robots carry shelves to workers, so workers spend less time walking to fetch items. This is more than a capital investment. It is a logistics system built on robotics, AI and real-time optimization algorithms.

The robots themselves (capital) are fairly simple. The real value is in the algorithms that coordinate hundreds of robots, thousands of workers and millions of items in real time. That coordination runs on proprietary technology Amazon has developed and refined over many years.

2. Predictive Analytics and Demand Forecasting

Amazon's AI systems analyse huge volumes of data to predict consumer demand, decide where to place inventory and anticipate supply chain disruptions. This lets Amazon position products near likely buyers before an order is placed, a practice known as "anticipatory shipping".

The capability is purely technological. It needs no extra land, labour or physical capital. The advantage comes from the algorithms, the data and the digital infrastructure themselves.

3. AWS Cloud Computing

Amazon Web Services (AWS) is the world's leading cloud computing platform. It provides the digital infrastructure behind Amazon's own operations and behind millions of other businesses. Its scale and steady technical improvement produce increasing returns that reinforce Amazon's position.

AWS also shows non-rivalry at work. The same infrastructure serves millions of clients at once, and each client's use adds to the scale and efficiency of the system.

4. Supply Chain Optimization Algorithms

Amazon's supply chain depends heavily on algorithmic optimization. AI selects shipping routes, consolidates shipments and keeps transport costs down, working from real-time data drawn from millions of sources. The volume and speed of those decisions is beyond what any human team could manage.

5. Amazon Go and Just Walk Out Technology

Amazon Go stores have no traditional checkout. They rely on computer vision, sensor fusion and deep learning, so a customer can walk in, pick up what they want and leave, with the

purchase charged automatically to their account. Here the technology itself is the main source of value, and it changes how retail works.

D. Quantifying Amazon's Technological Capital

Amazon does not report "technological capital" as a line item in its financial statements, but the scale of its technological assets can be approximated

Table 4: Amazon's Technology-Related Expenditure (Approximate FY2025)

Category	Amount (USD Billions)
R&D Expenditure	~80-85
Capital Expenditure (Technology Infrastructure)	~40-45
Cloud Computing Investment	~30-35
AI and Machine Learning Investment	~15-20
Total Technology-Related Investment	~165-185

Source: Author's estimates based on public disclosures

For comparison, Amazon's total capital expenditure in 2025 is estimated at roughly $60-70 billion, most of it technology-related and not traditional property, plant and equipment.

E. Case Study Conclusion

Traditional factors alone cannot explain Amazon's success. Its competitive advantage is technological: its algorithms, data and digital infrastructure are the main sources of its market power. Amazon illustrates technology as a fifth factor of production, distinct from traditional capital, labour, land and entrepreneurship, and more valuable than any of them.

V. THE MEASUREMENT CRISIS

If technology really is a fifth factor of production, why is it so hard to see in official economic statistics? This section looks at the measurement problems and proposes some reforms.

A. The Productivity Paradox

Economists have long puzzled over a strange pattern. Computers, the internet and digital technology have spread everywhere, yet measured productivity growth has been fairly modest. Robert Solow (1987) summed it up: "You can see the computer age everywhere but in the productivity statistics."

This "productivity paradox" may be a measurement problem, not a real absence of gains. When output is measured the traditional way, much of the value that digital technology creates goes uncounted.

B. The Accounting Mismatch

Table 5: At the core of the problem, national accounts treat technology spending differently from traditional investment

Expenditure Type	Traditional Investment	Technology Investment (Current Treatment)	Proposed Treatment
Physical Machinery	Capitalized (GFCF)	Capitalized	Capitalized
Factory Construction	Capitalized (GFCF)	Capitalized	Capitalized
Software Development	Expensed	Expensed (or partially capitalized)	Capitalized as Intangible Asset
R&D	Expensed	Expensed	Capitalized as Intangible Asset
Data Acquisition	Expensed	Expensed	Capitalized as Intangible Asset
AI Training	Expensed	Expensed	Capitalized as Intangible Asset

Because of this mismatch, a good deal of technology-related investment is recorded as an expense. That lowers measured GDP in the current period, when it should be recognized as investment in future productive capacity.

C. Intangible Capital and National Accounts

Recognizing intangible capital, technology included, is one of the hardest problems in national income accounting. The OECD (2010) estimated that investment in intangible assets in advanced economies is about equal to, or larger than, investment in physical capital, yet much of it never reaches official statistics.

Table 6: Estimated Intangible Investment as % of GDP (Selected Countries, 2025)

Country	Intangible Investment (% of GDP	Traditional Investment (% of GDP)
United States	15-18%	18-20%
Germany	12-14%	19-21%
United Kingdom	14-16%	17-19%
South Korea	16-18%	22-24%
Japan	12-14%	20-22%

D. The Value of Free Digital Services

A further problem is the value of "free" digital services such as social media, search engines, email and open-source software. They generate a lot of consumer surplus that GDP does not capture.

Their value shows up in consumer welfare, not in monetary transactions. Someone who uses Google Search, Gmail and Google Maps benefits from all three, but none of that appears in any measure of output. The result is a considerable underestimate of economic activity in the digital age.

E. Proposed Measurement Reforms

To address these measurement problems, this paper proposes the following reforms:

- Capitalization of Intangible Assets: Software development, R&D and data acquisition should be capitalized as investment, not expensed.
- Intangible Capital Index (ICI): A new Intangible Capital Index should be introduced alongside Gross Fixed Capital Formation (GFCF) to track technology-related investment.
- Quality Adjustments: National accounts should do more to adjust for quality, so that improvements in digital goods over time are reflected.
- Shadow Pricing: The value of free digital services should be estimated and reported in satellite accounts.
- Data as an Asset: Data should be recognized as an economic asset and included in national balance sheets.

VI. POLICY IMPLICATIONS

Recognizing technology as a fifth factor of production has consequences for economic policy in several areas.

A. Depreciation Schedules

Traditional capital depreciates through physical wear and tear, and depreciation schedules run for 10-30 years. Technology loses value through obsolescence, often within 3-5 years. Tax codes should reflect this by allowing accelerated depreciation on technology-related assets.

1. R&D Tax Policy

How productive technology investment is depending heavily on R&D. Tax incentives such as the R&D tax credit should be expanded, and designed to encourage general-purpose technologies (AI, quantum computing and the like) that spill over widely.

2. Digital Services Taxation

Taxing digital services is contentious. Corporate tax rules built around physical presence fit poorly in a digital economy where value is created in intangible assets. Possible reforms include:

- Harmonizing digital tax rules across jurisdictions

- Taxing digital services according to where users are located
- Setting minimum effective tax rates for technology-intensive firms

B. Trade Policy

If technology is a factor of production, restricting technology flows is equivalent to restricting flows of labour or capital. Trade policy therefore has to take account of the following.

1. Technology as Strategic Infrastructure

Advanced technologies, particularly AI, semiconductor design and quantum computing, are now treated as strategic infrastructure, so trade restrictions on them carry national security implications.

2. Intellectual Property Protection

For technology to work well as a factor of production, intellectual property rights have to be protected. Too much protection, though, can stifle innovation by slowing the spread of knowledge. Trade policy needs to balance protection against access.

3. Technology Transfer and Development

Developing countries have long relied on technology transfer to speed up their development. If technology is recognized as a factor of production, international frameworks should make sure access to it is equitable, since it is a tool for development.

C. Labour Market Policy

Treating technology as a factor of production has real consequences for labour markets:

1. Automation and Displacement

AI and automation are likely to displace labour in routine and cognitive tasks. Policy has to deal with this through:

- Retraining and up skilling programmes for displaced workers
- Social safety nets that support incomes during transitions
- Education reforms that stress adaptability, critical thinking and digital literacy

2. Complementarity and Augmentation

Technology does not only displace labour. It also augments it. Demand is likely to grow for tasks that complement AI, such as prompt engineering, data curation and algorithm validation, and policy should support the skills those tasks need.

3. Income Distribution

If technology is a distinct factor of production, it earns a share of output. That raises the possibility that the returns go mostly to the owners of technology (firms and investors) and not to workers. Policy should address the resulting inequality through:

- Progressive taxation of technology rents
- Stronger labour market institutions

- Greater public investment in education and infrastructure

D. Competition Policy

Technology's non-rivalry and increasing returns tend toward natural monopoly, so competition policy has to adapt:

1. Data Access and Interoperability

Large technology firms collect vast datasets, and those datasets become barriers to entry. Rules on data portability and interoperability can help competition.

2. Algorithmic Collusion

AI algorithms can lead to collusion even where firms have made no explicit agreement. Competition authorities need the technical capacity to detect it.

3. Merger Review

Merger review traditionally looks at market share and price effects. In technology markets, a merger can reduce competition in innovation, for instance through the "killer acquisition" of a potential rival, without raising prices at once. Merger review has to take innovation effects into account.

E. Infrastructure Policy

Using technology as a factor of production depends on supporting infrastructure:

1. Digital Infrastructure

Reliable high-speed internet is as essential to the modern economy as roads and ports were to the industrial one. Investment in broadband, 5G and satellite internet should be a policy priority.

2. Data Infrastructure

Data is a core part of technological capital, so policies on data governance, security and availability matter a great deal.

3. Energy Infrastructure

Technology, and AI and data centres in particular, uses a lot of energy. Clean and reliable energy infrastructure is needed to support technology-driven growth.

VII. LIMITATIONS AND FUTURE RESEARCH

This analysis has limitations, and future research should address them.

A. Measurement and Quantification

This paper offers a theoretical framework for treating technology as a factor of production, but measuring technology capital empirically remains difficult. Future research should:

- Develop reliable methods for measuring technology capital at the firm and national level

- Run econometric studies that estimate the elasticity of output with respect to technology capital
- Build technology capital accounts to sit alongside traditional national accounts

B. Heterogeneity of Technology

Not all technology is equally productive. Some technologies, such as AI or electricity, are general-purpose and change the whole economy. Others are narrow and tied to one sector. Future research should separate the types of technology and look at their different effects on production.

C. Distributional Effects

Recognizing technology as a factor of production matters for how income is distributed. Future research should examine:

- How returns to technology are shared among labour, capital and the owners of technology
- What this means for inequality and social welfare
- Which policies could make the benefits of technology more equitably shared

D. Global Perspectives

This paper has concentrated on advanced economies, but technology as a factor of production means something different for developing countries:

- Technology may speed up catch-up growth
- Technology transfer may be critical for development
- Digital divides may widen global inequality

Future research should study technology as a factor of production in the global economy, and from the perspective of developing countries.

E. The Ownership Question

If technology is a factor of production, who owns it? Technology often behaves like a public good. Open-source AI models, for example, are available to everyone. That challenges ordinary ideas of property rights and market allocation. Future research should look at models for governing technology as a collectively owned factor of production.

F. The Next Technological Revolution

This paper has dealt with the current generation of digital technologies. Emerging ones, including quantum computing, advanced AI, biotechnology and nanotechnology, may matter even more for production. Future research should anticipate them and ask what they mean for factor theory.

VIII. CONCLUSION

Economics students learn that there are four factors of production: land, labour, capital and entrepreneurship. For over two centuries that framework has explained how economic value is created. The digital transformation of the economy, however, has made it increasingly inadequate.

This paper has analysed technology as a fifth factor of production. The main findings are:

- Technology has distinctive characteristics that set it apart from the traditional factors: non-rivalry, increasing returns to scale, improvement with use and near-zero marginal cost of replication.
- Technology changes the productivity of the traditional factors. It does not just sit alongside land, labour, capital and entrepreneurship; it runs through them and amplifies their productivity.
- Technology is a meta-factor. It provides the architecture on which the traditional factors operate and sets the productivity ceiling for the whole economy.
- Technology matters empirically. The Amazon case study shows that technology-intensive firms create enormous value from their technological assets, often more than from their physical ones.
- Measurement is a problem. National accounts do not treat technology as investment, which feeds the productivity paradox and leads to an underestimate of economic activity.
- Policy has to change. Recognizing technology as a factor of production affects taxation, trade, labour policy, and competition policy and infrastructure investment.

Technology has joined the list of contenders for the status of a factor of production, and the evidence in this paper suggests it has earned its place in economic theory and policy. It is more than a tool or an externality. It is a basic input to production, as essential to the modern economy as labour and capital were to the industrial age.

Economists, policymakers and business leaders now face a clear task: build technology into our analytical frameworks, update our measurement systems, and design policies that make use of its productive potential while sharing the benefits widely. Analysing technology as a fifth factor of production is not an academic exercise. We need it to understand and shape the economic future.

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