

Online Supplement: The Adoption-Impairment Paradox

This supplement collects non-core detail moved from the main text under the Research Articles word limit. It contains no investment recommendation, no target price and no trading advice. All figures are as stated in the main text and carry the same source labels.

S1. Update note for Section 6 (29 October 2026)

Two dated items frame the sections that surround this page. The first updates the deployment clock of Section 6; the second anchors the financing-cost range of Section 7 in the most recent primary monetary-policy source. Neither adds a new finding, and neither repeats material developed in the companion papers.

Update note for Section 6, as of 29 October 2026: live items on the deployment clock. Four dated items are pending at the time of writing and are listed here as items to watch, not as findings: (i) the air-permit decision for Project Jupiter in New Mexico (Yucca Growth Infrastructure; a 2,462 MW Bloom fuel-cell design, with the Green Chile pipeline scheduled in service on 1 February 2027 and a force majeure notice dated 24 September 2026; no delivered MW has been found), with a New Mexico Environment Department decision deadline of 23 November 2026 that may slip to 18 December 2026 and a hearing on 7 December 2026 in Sunland Park; (ii) the next meeting of the Federal Open Market Committee, on 8-9 December 2026; (iii) Oracle's next quarterly filing on Form 10-Q; and (iv) any update to the Lawrence Berkeley National Laboratory interconnection-queue study (Rand et al., 2026), or to International Atomic Energy Agency reporting relied on in the companion papers. No item on this list is treated as a fact before it occurs and is verified from a primary source. The rule for using them is stated in advance: a verified outcome changes the weights attached to the deployment-clock scenarios of Sections 6 and 7 - which constraint binds, and for how long - and does not, by itself, change the thesis of this paper, which rests on the queue, substitution and adoption mechanisms documented above. An unverified outcome, in either direction, changes nothing in the text.

S2. Cross-reference for Section 7: the policy-rate anchor (29 October 2026)

Cross-reference for Section 7: the policy-rate anchor, updated 29 October 2026. The financing-cost range used in Section 7 is a scenario range, not a forecast of policy. Its current official anchor is the statement of the Federal Open Market Committee of 28 October 2026 (Board of Governors of the Federal Reserve System, 2026), which maintained the target range for the federal funds rate at 3-3/4 to 4 percent by a 10-2 vote, Lisa D. Cook and Beth M. Hammack dissenting in favour of raising the range by 1/4 percentage point. The statement describes economic activity as expanding at a strong pace and inflation as remaining elevated, and records that the accumulation of more information will help the Committee determine the stance that ensures a timely return of inflation to its 2 percent goal. The accompanying Implementation Note set interest on reserve balances at 3.90 percent, effective 29 October 2026. Treasury par yields for 28 October 2026 were mirror-reported at 5.05 percent for the ten-year, 4.67 percent for the two-year and 5.37 percent for the thirty-year; those figures are mirror-reported values, not Treasury-page closes, and are not used as an anchor in this paper. A December increase of 25 basis points, modelled as a scenario in the companion finance paper, remains a hypothetical scenario: it is not a decision, not a forecast and not an announced path. The full rate-sensitivity grid is developed in the finance paper and is not repeated here. For this paper the decision matters only through the deployment clock of Section 6: a policy rate held at this level, with both dissents pointing toward an increase rather than a cut, leaves the financing-cost scenarios of Table 3 anchored where they are while sites wait for power.

S3. Later platforms: space, subsea and tidal power (full text of Section 12.1.1)

Two proposed successors to the terrestrial campus are sometimes offered as reasons to discount the paradox, and each is treated here as a short cross-reference only, because neither changes the horizon this paper examines. Orbital computation rests on real physics - abundant solar power and radiative cooling - and has been demonstrated in orbit, but only at roughly the one-kilowatt scale: a single accelerator-class device running a small model, not a facility. Its economics turn on launch cost. Independent and proponent estimates place cost competitiveness near \$500 per kilogram and energy parity below \$200 per kilogram, against roughly \$1,500 per kilogram for current heavy-lift list prices, which puts general parity no earlier than the mid-2030s even on optimistic assumptions; hardware in orbit is unserviceable and is retired on a cycle of about five years; and latency suits training and batch inference, not interactive workloads. Subsea computation has the opposite profile: it has been demonstrated and worked. Microsoft's Natick experiment (Microsoft, 2024; company-reported) recorded a server failure rate of 0.7% against 5.9% for its land-based comparator - roughly one eighth - yet Microsoft ended the programme in 2024, because a sealed pod cannot be opened and upgraded at the cadence of GPU generations: reliability without upgradability loses to the substitution mechanism of Section 3. Tidal-powered proposals remain at the study and permit stage, with no operating facility at scale. The common lesson is that successor platforms are themselves generational technologies. They extend the obsolescence tail beyond the fifteen-to-nineteen-year leases - a ground campus is best understood as an asset with a window, not a permanence - but they arrive too late, and upgrade too slowly, to rescue hardware bought today.

S4. Note on sources: figure list and labelling catalogue for reported figures

Company figures used in the illustrative scenarios (capital expenditure of \$55.7 billion; free cash flow of -\$23.68 billion; claim stack of \$457.1 billion; uncommenced leases of \$288.0 billion; five-year CDS spread of 261 basis points (8 October 2026 print, not a current quote; later reported prints were higher, as documented in the companion finance paper); sum-of-the-parts value of \$95.00) are those documented from public filings and market data in the companion finance paper and are reproduced here without alteration. The incremental gross margin of 34% (against 72% historically) is an author-illustrative assumption, not a figure disclosed in Oracle's filings, and is labelled as such at each use.

All other figures are reported, not official, and are labelled at first use: neocloud capacities are company- and tracker-reported (contracted is not energised, and no figure is an audited capacity figure); accelerator prices are October 2026 company-published rate cards with differing configurations, not transaction prices; the 2014 reductions are company-announced list prices (Google, Amazon Web Services and Microsoft, 2014); transformer lead times are industry-reported ranges (Wood Mackenzie) - no single public report title or date was verified, the 80-210 week range for large units is verified only as Wood Mackenzie data quoted in the National Infrastructure Advisory Council draft and the North American Electric Reliability Corporation Summer Reliability Assessment 2025, and no continuous official series exists; the property-value studies are working papers and an industry analysis reaching opposite conclusions (Schlauch and Greenhill, 2026; Priest, 2026; Realtor.com, 2026), none peer-reviewed - for Priest (2026), the author is Alex Priest of the University of Rochester, and no SSRN number is given because none was found; the Memphis account, including permit 01156-01PC, is press and regulatory reporting verified via the Southern Environmental Law Center and related reporting only, not from the county permit document itself or a Senate primary source, cited as such and used illustratively only, with no single outlet or filing relied on as core evidence; the Anthropoc valuation range in Section 12 is press reporting, not a filed price, while the filing itself is cited as Anthropoc (2026); and the Natick results are company-reported (Microsoft, 2024). News reporting is not used as core evidence for any number in this paper. The Section 12 (continued) cross-reference rests on Solow (1956), United Nations (2024), OECD (2025), Cazzaniga et al. (2024), ILO and NASK (2025), Brynjolfsson, Chandar and Chen (2025, working paper), Brynjolfsson, Li and Raymond (2025), IEA (2025) and FAO (2026, forecast); the AI-displacement-fertility claim is stated there as a hypothesis only, no figure depends on it, and no direct effect of data centres on crop yields is claimed.

The Section 12 cross-references rest on Solow (1956), United Nations (2024), OECD (2025), Cazzaniga et al. (2024), ILO and NASK (2025), Brynjolfsson, Chandar and Chen (2025, working paper), Brynjolfsson, Li and Raymond (2025), IEA (2025) and FAO (2026, forecast); the AI-displacement-fertility claim is stated there as a hypothesis only, no figure depends on it, and no direct effect of data centres on crop yields is claimed.

S5. Growth regimes, population, fertility, food and resources (full cross-reference)

Measured corporate growth can be produced in two regimes that are easily confused. In the first, growth is a monetary phenomenon: loose financial conditions lower the cost of capital, raise asset prices and allow revenue and valuations to expand without any corresponding expansion in the number of customers or in output per customer. In the second, growth is real and demographic: output grows because there are more producers and more consumers, and because output per worker rises. The post-war decades combined both: falling conflict and rising birth rates enlarged the consumer base on which the software industry was later built. The distinction is formal, not rhetorical. In the Solow steady state (Solow, 1956), sustained growth in output per worker comes from technological progress, while a higher population growth rate raises the investment needed merely to keep capital per worker constant. And the support-ratio identity, $Y/N = (L/N) \times (Y/L)$ - output per person equals the share of the population in work multiplied by output per worker - shows the two margins separately: aggregate demand can grow through N and through L/N , even when Y/L is unchanged, and it contracts through the same margins when population and the working share fall. A twenty-year break-even, as in Section 7, is therefore a bet on the second regime, not the first: liquidity can refinance a claim stack, but only people, working and consuming, can service it.

Section 2 argued that adoption turns over with cohorts. Survey evidence is consistent with a steep age gradient. The OECD (2025) finds generative AI use and optimism concentrated among the young - over 75% of respondents under 35 view it as useful - while AI-related training in the last twelve months was reported by 46% of those aged 26-35 against under 20% of those aged 55 and over. The generation that must be retrained is, on this evidence, the generation least engaged with it: the transition cohort bears the retraining cost, and the native cohort has not yet replaced it. This is a statement about timing, not eventual capability.

The labour evidence runs in both directions. On exposure, IMF staff estimate that almost 40% of global employment is exposed to AI, with about 60% exposed in advanced economies and roughly half of the exposed jobs in those economies positioned to benefit rather than lose (Cazzaniga et al., 2024). The ILO's refined global index similarly concludes that transformation is more likely than replacement for most exposed occupations, with clerical work the most exposed (ILO and NASK, 2025). On observed outcomes, payroll data show early-career workers aged 22-25 in the most AI-exposed occupations experiencing a 13% relative decline in employment since late 2022, concentrated where AI automates rather than augments (Brynjolfsson, Chandar and Chen, 2025, working paper). On augmentation, a large field study finds generative AI raising issue resolution by about 14% on average, with the largest gains for less experienced workers (Brynjolfsson, Li and Raymond, 2025). Exposure is not displacement, and augmentation is not absorption. Together these studies establish only the narrower point this paper needs: adjustment is real, uneven by age and task, and slower than installation.

Two claims circulate in this debate and neither is established. There is no established evidence that AI raises fertility. The converse claim - that AI-driven displacement lowers incomes, raises anxiety during a forced occupational transition, and thereby lowers fertility in the transition generation - is a *hypothesis* only: it is a plausible chain through income and uncertainty, it is consistent with the age pattern above, and it has not been estimated. It is recorded here as a hypothesis to be tested by the companion papers, not as a finding of this one, and no number in Sections 7 or 8 depends on it. What is established is the demographic starting point, and it requires two corrections to common versions of the argument (United Nations, 2024). China has recorded negative population growth since 2022 and South Korea a natural decrease since 2020, and both have fertility far below replacement - about 1.0 births per woman in China and about 0.7-0.8 in South Korea. India is different: its total fertility rate, at about 1.96, is also below replacement, but its total population is *still growing* on demographic momentum, and is projected by the United Nations to keep growing to about 1.69 billion around 2054 before peaking. Below-replacement fertility and a falling population are therefore not the same statement, and conflating them overstates the near-term demand contraction. Finally, China and India together account for about 34.9% of world population - about one-third, not approaching one-half - which is large enough for their trajectories to set the global demand backdrop without exaggeration. Globally, the United Nations projects population rising from 8.2 billion in 2024 to a peak of about 10.3 billion in the mid-2080s: the demographic tailwind of the post-war regime is fading in the largest economies first, which is precisely the horizon over which Section 7's twenty-year row must be serviced.

A parallel correction applies to food. Precision agriculture is often credited with raising yields per hectare, but the gains usually quoted are modelled potentials from scenarios, not observed increases in global tonnes per hectare, and they should not be cited as realised. Weather and geopolitics, by contrast, move realised supply now: the FAO's Food Outlook forecasts global cereal output declining by about 2.0% in 2026, with wheat down about 3.8%, on smaller harvests among major exporters and on geopolitical and weather risks (FAO, 2026, forecast, not outcome); and the FAO-WMO assessment of extreme heat projects staple yield losses of about 4-10% per degree Celsius of additional warming for maize and wheat. This paper does *not* claim that data centres lower crop yields directly, and no such mechanism is asserted. The defensible claim is narrower and local: data centres compete for the same electricity, water, land and grid capacity that other users, including agriculture and food processing, also need, so their cost is an opportunity cost set locally - the subject of Section 6 - rather than a global yield effect. The scale of that competition is growing: the International Energy Agency estimates data centres consumed about 415 TWh in 2024, about 1.5% of global electricity, rising in its base case to about 945-950 TWh by 2030 (International Energy Agency, 2025). Whether that resource draw is repaid depends on the algorithmic-success branch of Section 9; in the branch where it is not, the draw is a real resource cost incurred for capacity that the paradox impairs. The full food, war and fertility model - including the Strait of Hormuz transmission chain - is developed in the companion geopolitics paper, and the financing consequences in the companion finance paper; both are deferred to there.

S6. Workload portability and contracted demand (full text of Section 12.1.2)

A final cross-reference concerns contracted demand, whose financial modelling belongs to the companion finance paper and is not repeated here. The technological fact is portability. Frontier training and inference workloads are built on standard frameworks, are containerised, and can be moved between clouds at switching costs that are low relative to the price dispersion documented in Section 5; a signed backlog therefore records intended demand, not captive demand, and it does not switch off the price mechanism. The point is visible in the customer side of the market. Anthropic, whose registration statement on Form S-1 was filed on 26 October 2026 (Anthropic, 2026) and which has not been priced - the widely reported valuation range of \$1.5-2 trillion is press reporting, not a filed price - reported first-half 2026 revenue of \$16.3 billion and cloud commitments of roughly \$450 billion over seven to ten years placed with Google, Amazon Web Services and Microsoft. No Oracle commitment appears in that list. The fastest-growing demand in the market is thus contracted, in the main, to the capacity of rivals. Demand growth and demand capture are different variables, and a technology assessment that treats a backlog as insulation from competition has confused the two.

S7. Ownership structures and the four supply tracks (full text of Section 5)

Ownership structures multiply the tracks further, and they differ by firm in ways a supply census must respect. Meta's Hyperion campus is held through a joint venture in which Blue Owl holds 80%, with Meta leasing the capacity back: hyperscaler demand, third-party balance sheet. Amazon and Google predominantly self-build and own. Microsoft mixes self-build, leases and neocloud contracts. Oracle, the case of the companion papers, leases campuses built by others - Crusoe, Vantage and STACK among them - so its capacity arrives through the landlord track. Summing the four tracks - self-build, joint venture, landlord lease and neocloud contract - is the only correct way to count future supply, and it is a sum no participant controls. That is the diffusion point of this section. When a technology's supply is produced by four independent organisational forms, each expanding on its own financing timetable, restraint by any one supplier cannot hold the price: the withheld workload is simply served by another track. Price competition in AI computation is therefore best understood not as a strategic choice that firms might avoid, but as the equilibrium of a diffusion process in which the means of supply have themselves diffused. The financial consequences of the resulting margin compression are computed in the companion finance paper and are not repeated here; the claim of this section is the prior one, that the supply mechanism makes the compression structural.

S8. Consent, house-price evidence and behind-the-meter generation (full text of Section 6)

Consent is the second gate, and it is not a formality. Community opposition to data centre siting recurs, across jurisdictions, on a consistent set of grounds: upward pressure on local electricity prices, water consumption, noise - including the testing of banks of standby diesel generators - air emissions, loss of open land, and feared effects on nearby house prices. For the deployment clock, the perception does the work whether or not the feared effect materialises, because perception is what planning hearings, permit appeals and litigation are made of. The measured evidence on house prices is genuinely divided, and this paper reports the division rather than selecting from it. An Energy Institute at Haas working paper (Schlauch and Greenhill, 2026; working paper, not peer-reviewed), using transactions, finds prices about 3% lower within three miles over five years and about 7.2% lower within one mile, with an aggregate effect of \$20.6 billion. A Virginia working paper by Alex Priest (Priest, 2026; working paper, not peer-reviewed), using air permits and ZIP-code price indices, finds an effect that is small and slightly positive, with confidence intervals excluding large declines. A Realtor.com industry analysis (Realtor.com, 2026; industry analysis, not peer-reviewed) of 43 ZIP codes over 2019-2025 finds no meaningful effect on values, while the share of sales within five miles rises from 0.67% to about 1.5%. The three are reconcilable in method - transaction studies can detect a sub-mile effect that ZIP-code averages dilute, and announcement, permitting and opening are different treatment dates - but none is peer-reviewed, and the honest summary is disagreement. What is not in disagreement is the political fact: residents act on the fear, and projects are delayed, conditioned or refused accordingly.

Bypassing the grid does not bypass compliance; it exchanges one gate for another. Behind-the-meter gas generation is now common precisely because it is faster than a queue, but the fast options are the least efficient ones: simple-cycle gas turbines convert fuel to electricity at about 33-37% efficiency, against about 49-54% for combined-cycle plant, so the speed premium is paid in fuel and emissions per megawatt-hour. Air permits bind where grid studies no longer do. The Memphis case, as reported in press and regulatory reporting (xAI Colossus, Memphis, 2025-2026; see Note on sources), is illustrative: aerial counts at xAI's Colossus site showed about thirty gas turbines, a county air permit (permit 01156-01PC, running from 2 July 2025 to 2 January 2027 and covering fifteen turbines totalling 247.2 megawatts (MW), as reported via the Southern Environmental Law Center and related reporting, not verified from the county permit document itself) was obtained in 2025 only after environmental groups threatened suit over unpermitted operation, and a Senate committee inquiry followed in 2026. Siting at the other extreme - desert or waterside - trades constraints rather than removing them. Desert sites can use dry or closed-loop cooling at near-zero water consumption, at the cost of additional electricity for cooling, and siting an evaporatively cooled campus in a desert inverts that bargain into a water conflict. River and reservoir cooling can cut cooling energy substantially, but intake, discharge temperature and environmental permits are site-specific and contestable, and remoteness itself is costly: a site far from fibre routes, grid capacity and labour has solved the consent problem by recreating the connection problem.

S9. The crypto-GPU precedent (full text of Section 10)

The mechanism of Sections 3 and 9 has already run once, in miniature and at high speed, in cryptocurrency mining - and the episode is offered strictly as a historical analogy, a rhyme in the sense of Section 2, not as a prediction that AI infrastructure will follow the same path to the same end. While mining algorithms were unfixed and varied across coins, miners rationally used general-purpose Nvidia GPUs: the flexible tool for an unsettled workload, exactly as in Section 3. As particular algorithms stabilised and volumes grew, custom ASIC miners were built for them, performing the fixed operations at a fraction of the energy cost. At that point GPU mining of those coins became uneconomic - not because the GPUs had worn out, and not because they had become slower, but because the price of the computation they sold was now set by a purpose-built rival. Second-hand GPUs flooded resale markets, prices for used cards collapsed, and inventory that participants had hoarded during the shortage was written down, in some cases hardware that had barely been run.

Every element of the paradox is present in the episode. The flexible asset was correct at purchase. Progress - the stabilisation of the workload - is what destroyed it. The impairment arrived through price, ahead of any physical failure, and it arrived for all holders simultaneously because the trigger was common. And the hoarding that amplified the losses was individually rational throughout. The disanalogies are equally instructive and must be kept in view. AI computation serves a far broader and more durable demand than any single mining algorithm; training workloads continue to evolve in ways that reward flexibility; and the firms building AI infrastructure are large, diversified enterprises rather than marginal miners. The analogy therefore establishes possibility and mechanism, not destiny. What it removes is the defence that the substitution sequence is unprecedented or merely theoretical. It has happened, to this class of asset, for these reasons, within the professional lifetime of the investors now pricing the same class of asset again.

S10. Price history and transformer lead times (full text)

The price consequence of multi-track supply is not conjecture; cloud computing has run this experiment before. In March 2014 Google cut Compute Engine list prices by 32% and storage prices by 68%; within days Amazon Web Services cut server prices by up to 40% and storage by up to 65%, and Microsoft followed with reductions of a similar order on Azure (Google, Amazon Web Services and Microsoft, 2014; company-announced list prices, not transaction prices). No firm in that sequence was behaving irrationally. Each was defending utilisation of capacity already built, against rivals holding the same sunk capacity. Systematic study of the longer series (Byrne, Corrado and Sichel, 2018, 2021) constructs hedonic, quality-adjusted price indexes for Amazon Web Services and finds prices falling at average annual rates of about 7% for compute over 2009-2016, more than 11% for database services over 2010-2016 and about 17% for storage over 2009-2016, with declines accelerating to double-digit rates from the beginning of 2014: commoditisation is the historical norm for standardised cloud resources, not a tail event. The current market already shows the same dispersion at the frontier. On published rate cards for October 2026, a B300 accelerator is offered at about \$9.50 per GPU-hour by Nebius against about \$17.80 by Amazon Web Services. The configurations behind rate cards differ, so the figures are not a like-for-like performance benchmark, and rate-card figures are company-published list prices, not observed transaction prices or audited market prices; what they establish is narrower and sufficient - the same accelerator generation is simultaneously sold at prices differing by a factor approaching two, which is what a market looks like before, not after, its prices converge.

Grid interconnection is a queue, not a purchase. In the interconnection queue study of Lawrence Berkeley National Laboratory (Rand et al., 2026), 2,061 gigawatts (GW) of capacity was active in queues at the end of 2025, the median time from queue entry to commercial operation for projects that are built is now more than five years, against under two years in the late 2000s, 549 GW had an executed interconnection agreement but was not yet in operation, and completion is the exception: of the capacity that entered queues between 2000 and 2020, only about 13% had been built by the end of 2025, while about 75% was withdrawn. Withdrawals do not shorten the queue mechanically, because the studies behind each project assume the projects ahead of it; when one withdraws, the studies for those behind it may have to be redone. The process is also fragmented rather than national: a regional grid operator's interconnection studies, the serving utility's network upgrades, state and local permits and environmental review proceed as separate gates, in varying order, with no single authority able to quote a shortest lawful path. Equipment queues run in parallel. Large power transformers, the long-lead item in most substation work, carry industry-reported lead times for large units of 80-210 weeks as Wood Mackenzie data quoted in the National Infrastructure Advisory Council draft and the North American Electric Reliability Corporation Summer Reliability Assessment 2025 (Wood Mackenzie, industry reporting; no single public Wood Mackenzie report title or date was verified), against about one year before the current build-out; no continuous official series exists, and the figures should be read as reported ranges rather than as a measured index. A project that has cleared the queue can therefore still wait on the transformer that the queue clearance requires.