The Financial Economics of U.S. Public-Private Partnerships

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Abstract

Public-private partnerships (P3s) are the main contractual form through which private capital owns and finances U.S. public infrastructure, yet no database decomposes their capital stacks or records the risk their investors agreed to bear. I introduce the first project-level database of U.S. P3 financing: hand-collected capital stacks, contract terms, project characteristics, and private sponsors for 1,815 infrastructure projects. Because the concession fixes demand risk at financial close, the data show whether financial investors systematically bear more project risk or selectively target positions where that risk has been contractually removed. Using construction-led projects as the benchmark, I find that projects led by financial investors are 23 percentage points more likely to carry an availability payment, which shifts demand risk to the public sector, and operate at a higher leverage of 0.86 in those availability-payment projects, compared to 0.67 for similar projects led by construction firms. In contrast, when financial investors merely participate in a construction-led project, the project carries demand risk as often as one sponsored by construction firms alone. Finally, financial investors add complexity to their capital investment, using 0.29 to 0.47 more instruments than the 1.6 of a construction-only project. Although contract and capital structure are jointly determined, this cross-sectional sorting holds within asset types and across project sizes and contract forms.

Keywords: Public-private partnerships, Private capital, Risk allocation, Capital structure, Infrastructure finance, Subsidized credit

JEL classifications: G23, G32, H54, H44, L33

1 Introduction

Public-private partnerships (P3s) are the main contractual form through which private investors own and finance U.S. public infrastructure. Under a P3, a government contracts with a private consortium to design, build, finance, operate, and maintain an asset—such as a highway, a courthouse, a student housing complex, or a water treatment plant—typically for twenty to fifty years. The consortium capitalizes a standalone special purpose vehicle whose sole asset is the project. Consequently, each P3 operates as a single-asset firm with its own capital structure, establishing the sector as an asset class in its own right for pension and infrastructure funds (Andonov et al., 2021). Successive administrations have promoted P3s as a way to close a multi-trillion-dollar infrastructure shortfall (American Society of Civil Engineers, 2024; Federal Highway Administration, 2024; White House, 2018). Furthermore, the federal government subsidizes this private capital directly; tax-exempt private activity bonds and below-market TIFIA loans have collectively supported over $100 billion of surface transportation investment since the late 1990s (Congressional Budget Office, 2020). However, despite the scale of capital deployed and the policy attention it receives, little is known about how these projects are actually financed. No database records the extent of private capital participation, the instruments private sponsors use, or the allocation of project risk. Indeed, Lucas and Montesinos (2021) identify this opacity as the central obstacle to valuing private investment in public infrastructure.

This empirical gap matters beyond infrastructure, as it bears on a central question in the finance literature regarding the role of private capital in the public sector.When private financial capital enters an industry that governments fund, does it deliver a service by

bearing risk the public sector would otherwise hold, or does it position itself where risk has already been removed to generate a return on public money? The first view, which I call the *risk-bearer* view, holds that private capital absorbs construction and demand risk, and that its capital at risk disciplines delivery. The second, the *cream-skimming* view, holds that financial investors take positions stripped of economic risk by contract or subsidy, extracting rents by intermediating public payments. Studies of higher education (Eaton et al., 2020), nursing homes (Gupta et al., 2024), hospitals (Gao et al., 2025; Liu, 2022), ambulance services (Ellis and Esson, 2024), and life insurance (Kirti and Sarin, 2024) document outcomes largely consistent with the second view. However, the evidence is not one-sided. In infrastructure itself, Howell et al. (2026) find that transferring an airport to private hands does not inherently improve performance, whereas private equity ownership specifically raises efficiency, traffic, and service quality. Thus, the identity of the private owner matters more than privatization itself. In all of these settings, however, the risk allocation itself is unobserved. Risk-bearing is inferred from what happens after the ownership change, and an ex-post outcome looks the same for an owner who managed risk well and for one who contracted it away.

In this paper, I use U.S. P3s to observe the allocation of risk directly and ask whether financial investors bear more project risk or select positions from which it has been contractually removed. Two features of the setting make this question answerable. First, the concession agreement fixes the allocation of demand risk at financial close. Under an availability-payment contract, the government pays a fixed charge to keep the asset in service regardless of its usage. An availability payment removes demand risk only. Construction cost, operating cost, lifecycle cost and performance deductions remain with the private partner under both contract forms, so the comparison in this paper concerns contracted demand risk and makes no claim

about the total risk of a project. Conversely, under a demand-risk contract, the private partner collects tolls or user fees and absorbs volume fluctuations. Consequently, risk-bearing is an explicit contract term recorded on the exact same day as the capital stack. Second, the market supplies an internal benchmark. Construction firms invest their own equity in these assets; in fact, nearly three-quarters of the privately financed projects in the sample feature no financial investor at all. This allows projects sponsored solely by construction firms to serve as a natural control group for those led by financial investors within the same sectors. I find that financial investors do both, depending entirely on consortium control. A financial investor that leads the consortium systematically sorts into contracts that return demand risk to the public sector and highly levers the contracted payment stream. In contrast, a financial investor participating as a minority partner under a construction firm accepts the risk allocation that the construction lead negotiated.

To do so, I construct the first project-level record of how U.S. P3s are financed. The master project list merges and deduplicates seven distinct sources: two federal inventories, a global P3 database, a long-running trade publication that tracks capital structures, and three specialized rosters covering the water sector, large transport projects, and the state of Texas. Because no single source spans the market, and the specialized rosters cover segments systematically underrepresented by general databases, this union represents the most comprehensive accounting of the sector to date. For each of the 1,815 U.S. infrastructure projects identified, I record the capital stack, contract terms, project characteristics, and private sponsors. Of these, 796 are P3s by delivery mode, and 392 are privately financed projects that reached financial close with a recorded private capital total. These 392 projects represent $265 billion in capital expenditure, of which $217 billion is privately financed.

Every financing figure is hand-collected from primary sources, including sponsoring-agency disclosures, financial close summaries, press releases, and municipal bond official statements filed on EMMA—and archived with a verbatim quotation and its source URL. The dataset was constructed through a rigorous four-pass methodology: a large language model (LLM) search of the public record, manual verification of each project against primary documents, an independent LLM model audit of the recorded values, and a final manual adjudication of every discrepancy.

The data identify the distinct composition of each private consortium, as its members are not interchangeable. An *operating sponsor* is a construction or facilities firm whose infrastructure arm invests primarily to secure the underlying physical work; thus, its project equity acts as a cost of sales for an operational business that outlives the project. A *financial sponsor* is a fund or developer-investor with no internal construction apparatus; it subcontracts the build and earns its return strictly on the equity stake. I match every private entity named in the project documents to firm-level data and classify it based on its primary business operations, ensuring that a contractor's captive investment arm is typed as operating, while a developer that subcontracts construction is typed as financial. I then distinguish projects in which a financial investor *leads* the consortium from those in which it merely *participates* under an operating lead, as the lead sponsor dictates the concession terms. A simple framework, detailed in Section 3, organizes this cross-sectional comparison. It isolates the effects driven by the mere *participation* of financial capital (namely, scale and structuring expertise) from the effects driven strictly by *control* (namely, contract choice and leverage).

I begin by documenting the market. Social infrastructure, encompassing schools, court-

houses, student housing, and civic buildings, accounts for 321 of the 796 P3s, outpacing transport (290) and utilities and environment (185), although transport commands $380 billion of the $528 billion in recorded project costs. Notably, the empirical literature on P3s has concentrated almost exclusively on toll roads, which represent just one subsector of transport. Across the broader market, private capital supplies 84 percent of project costs on average, and the median project is entirely privately financed, rendering the public contribution a residual. Private capital also arrives in three distinct financing architectures: corporate balance-sheet financing with no project-level debt, conduit bond structures with no sponsor equity, and traditional project finance incorporating both. Because leverage functions as a continuous ratio only in the third architecture, pooling the three treats distinct regime choices as points on a continuous leverage distribution that does not actually exist. Consequently, I report the financial architecture as an outcome in its own right and confine continuous leverage to the interior case.

The first main finding is that availability payments are substantially more common where a financial investor leads the consortium. Among projects with a recorded concession, 54.2 percent of financial-led projects utilize an availability-payment arrangement, compared to just 22.5 percent of operating-only projects. Exposure to full demand risk exhibits the inverse pattern: 37.3 percent for financial-led versus 68.1 percent for operating-only. Conditioning on sub-sector, decade, and project size, financial-led projects are 23.0 percentage points more likely to carry an availability payment and 22.8 percentage points less likely to bear full demand risk; furthermore, an index of the demand risk borne privately falls by 0.46 on a three-point scale. Relative to the 22.5 percent base rate, the availability estimate implies that financial control roughly doubles the probability of an availability-payment contract.

Because the comparison holds the asset type fixed, it is made among roads, among transit facilities, or among student-housing projects, and not between them. The availability result remains robust to controlling for the number of lifecycle tasks bundled in the contract and for the number of private entities recorded on the project.

Financial capital participating under an operating lead exhibits a starkly different pattern. The availability coefficient for this group is -0.113 and statistically indistinguishable from zero. In raw terms, 76.5 percent of these projects carry full demand risk — a higher share than operating-only projects — while their concessions are 8.8 years longer within availability deals, where the typical term is 25 to 30 years. These are massive projects, with a median cost of $460 million against $117 million for operating-only projects, and they utilize significantly more financing instruments than either of the other configurations. Financial capital appears to enter as a minority partner on deals where the equity requirement exceeds what a contractor can commit alone, strictly accepting the risk allocation the contractor negotiated. The divergence between these two configurations is the most precisely estimated result in the paper, and it provides a critical measurement insight for the broader literature on financial ownership. Specifically, a pooled indicator for whether a project has *any* financial investor aggregates two groups sitting on opposite sides of the operating-only benchmark, yielding an estimate near zero. A parallel masking effect is documented by Howell et al. (2026) regarding operational outcomes, where a broad privatization dummy obscures significant effects that only emerge when strictly isolating private equity ownership.

I next demonstrate that financial sponsors assume greater financial risk, partially offsetting the contractual operational risk they avoid. Within the traditional project-finance architecture, where leverage functions as a continuous and meaningful ratio, financial-led projects operate

with leverage 8.8 percentage points higher than operating-only projects. This represents a roughly 13 percent increase over the operating-only mean of 0.68, and the gap widens to 13.5 percentage points when restricting the measure to debt unambiguously isolated at the project level. Consistent with earlier findings, financial minority partners exhibit no such difference. The distinction between sponsor types thus lies in the composition of the risk borne, not merely its magnitude.

The distribution of this leverage across contract types helps adjudicate among the theoretical mechanisms driving it. The framework identifies four structural differences between sponsor types that could generate a leverage gap: capital depth, financial expertise, risk aversion, and an operating sponsor's exposure beyond its project equity. These mechanisms yield distinct predictions regarding the shape of the leverage gap across contract forms. For example, a sponsor with greater capacity to pledge collateral would deploy higher leverage across all contracts, whereas a highly risk-averse sponsor would lever least where the contract removes demand risk. Empirically, I find that the leverage gap is concentrated within availability contracts. Estimated separately by contract form, the financial-led gap is 19.4 percentage points under availability contracts and 5.0 points, indistinguishable from zero, under demand-risk contracts, and leverage lies between 0.67 and 0.72 in every sponsor-by-contract cell except financial-led availability deals, where it is 0.86. The two split-sample estimates are not formally tested against each other, so this pattern is suggestive. The point estimates are consistent with undiversified distress costs. Because an operating sponsor's exposure extends beyond its equity to the construction margin and long-term reputational relationships, it optimally halts borrowing well below the debt ceiling. Conversely, a financial sponsor's exposure is strictly limited to its committed equity, incentivizing it to borrow up

to the constraint. The dispersion of equity shares corroborates this channel: if a financial sponsor's equity is simply the residual dictated by a lender's maximum advance rate, its equity share should exhibit lower variance across projects. The data are consistent with this prediction, yielding a variance ratio of 2.17.

Financial-led projects do not obtain a larger share of subsidized credit than operating-only projects once the asset type is held fixed. The utilization of tax-exempt private activity bonds is similar across sponsor configurations (41.8 percent against 39.8 percent), and while the subsidized share of private capital is 17.1 percentage points higher for financial-led projects when only sector and decade are held fixed, the gap falls to 14.3 points and is not statistically significant at conventional levels within sub-sectors, on a sample of 78 projects. Therefore, the public support associated with financial control appears to be contractual, fundamentally differing from standard budgetary support in its accounting visibility. An availability payment commits the public grantor to a fixed, thirty-year charge irrespective of demand, a guarantee that is systematically more valuable to a sponsor operating at its borrowing ceiling. Unlike an appropriated grant, which is immediately visible in a municipal budget, a multi-decade availability commitment is an obligation that public accounting standards have only recently begun to recognize. Consequently, this form of risk-shifting remains largely obscured in standard fiscal statistics.

The primary alternative explanation for the availability result is that financial sponsors simply use the most comprehensive delivery modes and that such modes happen to be availability-based. I find no evidence for it. Controlling for the number of lifecycle tasks bundled leaves the estimate at 22.2 points, controlling for the number of private entities recorded leaves it at 22.0 points, and both controls together leave it at 20.9 points, each

statistically significant at the 1% level. Three limits should be stated plainly. First, because contract form and capital structure are negotiated jointly during procurement, the paper documents equilibrium sorting, and none of its estimates can be viewed as causal. Variation in contractual risk allocation that leaves the private capital stack unchanged would also answer a narrower question than the one asked here, since the allocation is set once, at contracting, and the margin that matters is which sponsors sign which contracts. Second, the comparison of the leverage gap across contract forms rests on 45 availability-payment projects, and the two split-sample estimates are not formally tested against each other, so that adjudication is only suggestive. Third, the paper makes no claim about welfare. A government may rationally prefer to retain demand risk, so a contract that returns it to the public sector is not by itself a bad bargain.

This paper contributes to three literatures. The first studies private ownership of services that governments fund, in higher education (Eaton et al., 2020), nursing homes (Gupta et al., 2024), hospitals (Gao et al., 2025; Liu, 2022), insurance (Kirti and Sarin, 2024), local news (Ewens et al., 2022), and failed banks (Johnston-Ross et al., 2025), and asks whether financial owners create value or capture it. Relative to these studies, I observe the risk the owner agreed to bear, so that selection into positions without demand risk can be separated from performance in positions that carry it, and I observe a benchmark of privately financed projects without financial investors inside the same market. The separation is the one drawn by work on cream-skimming under regulated prices in hospital care (Lee et al., 2025) and in ambulance services, where private equity operators compete with government-backed providers (Ellis and Esson, 2024); here the contract that allocates the risk is written down.

The second literature concerns private capital in public infrastructure. Recent work

documents the growing role of institutional capital in the asset class and its disappointing realized performance (Andonov et al., 2018, 2021; Andonov and Rauh, 2024), studies particular instruments, including private activity bonds (Knauer, 2023) and the tax equity that finances renewable generation (Garrett and Shive, 2022), and examines the delegation of these mandates to external managers (Andonov, 2024). A parallel literature documents what infrastructure costs and why: declining construction productivity (Goolsbee and Syverson, 2023), rising highway costs and their procurement roots (Brooks and Liscow, 2023; Liscow et al., 2023), and the lifecycle cost of long-lived assets (Mehrotra et al., 2024). Both strands work at a level above the individual project. Howell et al. (2026) study a close question and find that the type of owner, more than private ownership as such, governs how an infrastructure asset performs once it is in private hands; their object is privatization, in which the asset changes hands, whereas a P3 concession leaves it public. Relative to these studies, I observe the terms on which private capital took its position, and I supply the project-level capital stacks and contract terms that fund-level returns aggregate over, together with the identity of the investor holding each one. To my knowledge, this paper is the first systematic project-level record of how U.S. P3s are financed.

The third literature is the economics of P3 design, which models the allocation of risk and tasks between a government and a private partner as a design problem (Bennett and Iossa, 2006; Engel et al., 2013; Hart, 2003; Iossa and Martimort, 2012), together with the project finance literature on how a nonrecourse single-asset vehicle supports debt through its web of contracts (Brealey et al., 1996; Corielli et al., 2010; Esty, 2002). That work treats the allocation as a choice made by the grantor. The evidence here suggests that the identity of the private counterparty is associated with it as well.

The rest of the paper proceeds as follows. Section 2 describes the institutional setting and the market. Section 3 sets out the financing problem and the four differences between sponsor types that could produce the patterns documented here. Section 4 describes the data and the classification of sponsors. Section 5 reports what private capital does in these projects, Section 6 what changes when the investor is financial, and Section 7 concludes.

2 Institutional Background

In this section, I describe the market the paper studies: what gets built under a P3, how large these projects are, how their number has grown, what contracts govern their revenue, and how the money is assembled. To my knowledge, no prior work reports these dimensions for the U.S. market as a whole, so the description also serves as the paper's first set of results.

2.1 Public-Private Partnerships

Public infrastructure projects involve five stages: design, build, finance, operate, and maintain. Under traditional procurement, the government retains financing, operation, and maintenance, and contracts with private firms only for design and construction under separate agreements. A public-private partnership extends the private role by bundling several stages under one long-term contract. Definitions vary across jurisdictions (Fabre and Straub, 2023; Grimsey and Lewis, 2007), but two features are common. First, multiple stages are bundled, often over twenty to fifty years, so that the party building the asset internalizes the lifecycle consequences of how it builds (Bennett and Iossa, 2006; Hart, 2003). Second, risks that would otherwise sit with the government are transferred by explicit contractual provision (Engel

et al., 2013).

This economic definition differs from the policy framing, in which legislative and executive discussion treats the P3 primarily as a vehicle for attracting private capital (Federal Highway Administration, 2024; White House, 2018). The distinction matters for this paper because private financing is neither necessary nor universal. Of the 796 P3 projects in the sample, 615 are privately financed (585 under a delivery mode that includes private financing, and 30 lease-operate-maintain concessions in which the private partner pays an upfront concession fee), and the remaining 181 bundle tasks without private capital. I therefore follow the academic definition and treat private financing as a feature of the contract to be measured; whether a project is a P3 depends on bundling and risk transfer alone.

2.2 Delivery Modes and the Shape of the Market

Delivery mode specifies which stages the private firm undertakes, and one mode dominates. Design-Build-Finance-Operate-Maintain assigns the entire lifecycle to the private partner, typically for thirty to fifty years, and accounts for 457 of the 796 P3 projects, or 57 percent (Figure 1). The remaining modes each drop one stage or another. Design-Build-Finance adds construction financing that the government repays over a fixed period, Design-Build-Operate-Maintain adds long-term operation while the government finances, and lease structures transfer an existing asset in place of a new one. Panel B of Table 1 shows how sharply the modes differ in what they imply for the private balance sheet. Every project under a mode containing finance carries private capital by construction. Lease-operate-maintain concessions divide: in 30 of the 77, the private partner pays the grantor an upfront concession fee, which

it raises as equity and debt at the project level in the same way as a construction budget, and I count these leases as privately financed. The 181 projects under the remaining arrangements (chiefly Design-Build-Operate-Maintain, leases without an upfront fee and build-own-operate) bundle tasks with public money.

Social infrastructure accounts for more P3 projects than transport does (Figure 2). Community and public space, education, justice and public safety, and government administration together come to 321 projects, against 290 in transport, and water, waste, energy and digital infrastructure add a further 185. Roads are the largest single subsector, with 148 projects, but they remain one subsector within transport and less than a fifth of the market. Panel A of Table 1 shows that the sectors also differ in scale: the median transport P3 costs $440 million, against $110 million in social infrastructure and $43 million in utilities and environment. Studies restricted to highways therefore observe the largest projects and a small share of the market.

P3 activity is also recent and concentrated in time. Of the 569 projects with a dated financial close or construction start, 431 (76 percent) fall in 2010 or later, and Figure 3 shows the annual count rising from low single digits before the mid-1990s to roughly thirty to forty a year since 2020. However, the private-finance share of that activity is stable. The shaded portion of each bar, which marks projects bundled without private capital, is a roughly constant fraction throughout, so the growth is in the number of P3s, with the propensity of a P3 to carry private money roughly unchanged.

2.3 Concession Types and the Allocation of Revenue Risk

The contractual choice most consequential for financing is the allocation of revenue risk, and the data distinguish three arrangements that form a ladder of declining risk to the private partner. Under a *full demand-risk* concession, the private partner is paid directly by dispersed end users and bears the full volume risk of the asset; toll roads and parking facilities are the canonical cases. Under a *mitigated demand-risk* concession, the partner still sells a metered output, but a monopoly franchise, inelastic demand, or a contractual floor insulates revenue from short-run fluctuation; these are almost entirely water, wastewater, and contracted-power concessions in which the partner owns the asset and sells its output. Under an *availability-payment* concession, the partner bears no demand risk at all, since it is paid a fixed charge for keeping the asset available and meeting performance standards, whatever the usage. The ladder orders the three forms by demand risk alone. Under every form the private partner continues to bear construction cost, operating and lifecycle cost, and, under an availability payment, deductions for missed performance standards; a fixed payment that proves thin relative to those costs leaves its equity exposed.

A single sector can occupy any rung of this ladder, because the placement depends on whether the private partner sells the output and absorbs the volume risk of doing so; the type of asset is not decisive. Appendix A3 sets out the classification rules and the cases that required judgment.

Availability payments are a recent arrangement and a growing one. Figure 4 plots the three types by year. Full demand risk accounted for essentially all early concessions, whereas availability payments appear in volume only after the mid-2000s and now account for 167

of the 508 P3 projects with a recorded concession, or about a third. Panel (b) restricts the figure to transport, where the shift is sharpest and where several early toll concessions underperformed their traffic forecasts. The shift is usually explained as public-sector learning about demand forecasting. In Section 6, I show that the identity of the private investor moves with it.

2.4 Federal Credit Instruments

Two federal instruments support private financing. *Private Activity Bonds* are tax-exempt bonds issued by a state or local authority on behalf of a private sponsor, which give the sponsor access to the municipal market at below-market coupons; access requires a volume-cap allocation. *TIFIA loans* are direct federal loans at below-market rates, structurally subordinated to senior project debt, so they function as low-cost mezzanine financing; awards are discretionary and subject to eligibility thresholds. Both lower the cost of private capital, and the Congressional Budget Office estimates that the two have together supported over $100 billion of surface transportation investment since the late 1990s (Congressional Budget Office, 2020).

Federal grants differ from both instruments. A grant is a transfer into the capital stack, whereas the two credit instruments reduce the price of private funds, and in Section 3 I show that the two kinds of support enter the financing problem at different points.

2.5 Sponsors

The private party to a P3 is a consortium, and its members are not interchangeable. Two types recur. An *operating sponsor* is a construction or facilities firm whose infrastructure arm invests in order to secure the underlying work, so its project equity is a cost of sales for a business that outlives the project. A *financial sponsor* is a fund or developer-investor with no construction arm, which subcontracts the build and earns its return on the equity stake alone. For example, Skanska Infrastructure Development is an operating sponsor, while Plenary and Meridiam are financial sponsors.

The two types differ in what a project failure costs them, in the capital they can commit, and in their familiarity with financing instruments, and in Section 3 I show that each difference carries its own testable implication. Moreover, the sponsor holding the largest equity position also selects the concession, so it matters whether a financial investor participates in a consortium or controls it.

2.6 How P3 Projects Are Financed

Private capital dominates the capital stack of these projects, and public money is a minority contribution. Across the 392 projects in the analysis sample, which together represent $265 billion of capital expenditure, I find that the private share of project cost averages 84 percent and that its median is 100 percent (Table 2). State and local governments contribute 11 percent of the average project's cost and federal grants 4 percent. This pattern is the opposite of traditional procurement, in which the public share is the whole.

Within the private contribution, the instrument mix is more varied than either the

corporate-finance or the municipal-finance benchmark would suggest. Figure 5 classifies the 309 projects whose private stack is decomposed into four mutually exclusive categories. About a quarter carry no project-level debt at all, so the private contribution is entirely equity. Another 31 percent borrow privately without touching a federal instrument. The remaining 45 percent use a private activity bond or federal credit, and seven in ten of those use it *instead of* private debt; only three in ten combine the two. In the typical case, therefore, federal credit is the financing itself, and it serves as a top-up layer on a conventional project financing only in the minority of cases.

Figure 6 decomposes the same projects by source, twice. The aggregate bar pools dollars and is therefore dominated by the largest transactions, while the project-average bar weights every project alike. Two components move between them. Federal credit is 9.6 percent of pooled dollars and 3.6 percent of the average project, because TIFIA lending concentrates in a small number of very large transport deals, and private equity moves the other way, from 25.3 percent of dollars to 31.2 percent of the average project. Private activity bonds, in contrast, are nearly the same share on both measures, 26 to 27 percent, which suggests that they are used across the size distribution. Any statement about "the" P3 capital stack therefore has to specify which weighting it uses, and I report both throughout.

Equity remains a large component of the stack even though subsidized debt is available below market rates, which frictionless tradeoff reasoning would not predict. Government instruments also appear in only some capital stacks, which raises the question of whether they attract private capital or merely accompany it. In Section 3, I organize both patterns.

3 Conceptual Framework

In this section, I set out the financing problem facing a private investor in a P3, locate the two public instruments within it, and then ask what changes when the investor is a financial firm. Four differences between financial and operating investors are commonly invoked. I show that they are not observationally equivalent, and separating them is the purpose of the framework. Proofs are in Appendix A5.

3.1 The Financing Problem

The project. A single infrastructure asset costs $K > 0$, fixed contractually at financial close. Public money enters as a federal grant G_f and a state or local contribution G_{sl}, both determined outside the sponsor's problem, so the private capital requirement is

$$P \;=\; K - G_f - G_{sl}, \tag{1}$$

financed with equity $E \geq 0$ and project debt $D \geq 0$, $P = E + D$. The required return on equity ρ exceeds the cost of project debt r_d. The two public components are kept separate because they are set by different actors subject to different budgets, so a change in one need not be absorbed by the private side.

The concession. The contract $c \in \{A, R\}$ determines how the asset is paid for over an operating phase of length τ. Under an availability-payment concession ($c = A$) the grantor pays a fixed charge $\bar{x}$ per period conditional on the asset being available, and the private party bears no demand risk. Under a revenue-risk concession ($c = R$) the private party

collects user fees $\bar{x} + \varepsilon_t$ with $\varepsilon_t \sim (0, \sigma^2)$, $\sigma > 0$, and bears the volume risk. Risk allocation is thus a contract term, observed at financial close, and it need not be inferred from realized outcomes (Iossa and Martimort, 2012).

Debt capacity. Let $\Pi = \sum_{t=1}^{\tau} \bar{x}(1+r_d)^{-t}$ denote the present value of the expected payment stream. Lenders advance against pledgeable income (Holmstrom and Tirole, 1997):

$$D \;\leq\; \theta_c \, \Pi, \qquad \theta_A > \theta_R, \tag{2}$$

where $\theta_c \in (0, 1]$ is the fraction of expected cash flow that lenders accept as debt service. The ordering $\theta_A > \theta_R$ carries the contractual content of the framework, since a payment invariant to usage supports a lower debt service coverage ratio, so that a given expected cash flow pledges more (Blanc-Brude and Strange, 2007; Corielli et al., 2010). Absent this ordering, contract form is a risk-sharing arrangement with no financing consequence. Because the structure is single-asset and nonrecourse, (2) is the binding constraint; no firm-level balance sheet stands behind it (Brealey et al., 1996; Esty, 2002).

Government instruments. The two public instruments enter at different points. A grant raises G_f and lowers the private requirement one-for-one through (1). The relation is an accounting identity, so it ensures that a grant displaces some component of the stack without determining which. Whether the private stack, the state and local contribution, or both absorb the grant is an empirical question, and estimates of grants on private shares should be read accordingly. Subsidized credit, in contrast, operates on price. A tranche supplied at $r_s < r_d$ lowers the blended cost of the private stack without relaxing (2), so a given project

supports a larger private share.

Remark 1 (Instruments). Access to subsidized credit weakly raises the private share of project cost. A grant displaces private capital, the state and local contribution, or both, and the identity alone does not determine which.

Three financing architectures. The problem admits three solutions, each corresponding to a structure observed in practice. When $\theta_c \Pi$ is small relative to the fixed cost of arranging project debt, $D = 0$ and the sponsor funds the asset from its own balance sheet. When the asset is owned by an entity with no residual claimant, as with a $501(c)(3)$ conduit issuer, the equity term is absent and $D = P$. Between these corners lies project finance, with both instruments present. Leverage is defined as a ratio only in the interior case, which matters for measurement, since the three are distinct architectures and cannot be read as three points on one distribution.

3.2 Two Types of Private Investor

The problem above treats private capital as homogeneous, and I now distinguish two types. An *operating* sponsor is a construction or facilities firm whose infrastructure arm invests in order to secure the underlying work. A *financial* sponsor is a fund or developer-investor with no construction business, whose return derives from the equity stake alone. Four differences between them are commonly invoked, and I take each in turn.

Capital depth. A financial sponsor can commit equity beyond what a construction firm's balance sheet supports. Let $\bar{E}_O$ denote the operating sponsor's equity capacity, finite and small relative to the largest projects. Capital depth governs participation and scale. Its

implication for leverage is ambiguous, since an investor able to fund with equity has less need to borrow, while an investor allocating a fund across many assets has reason to lever each one. The two forces work in opposite directions, so capital depth makes no signed prediction about leverage.

Financial expertise. A financial sponsor is specialized in assembling capital structures and faces lower costs of arranging and administering each additional tranche. Expertise therefore concerns the composition of a given private contribution; for the same dollars committed, a more expert sponsor divides them across more instruments. Whether expertise also raises leverage depends on whether it raises the advance rate θ_c itself. If it does, the advantage appears under every contract form; if it does not, expertise and leverage are unrelated.

Risk aversion. A financial sponsor dislikes demand variance and sorts into contracts that eliminate it. A risk-averse equity holder in a project with certain cash flows has less reason to economize on equity, however, so its leverage advantage should be smallest precisely where the contract removes demand risk.

Undiversified distress cost. The operating sponsor's project equity supports a business that outlives the project. In distress it loses $\lambda > 0$ in addition to its equity: the construction margin on the project, the value of related contracts, and reputation carried on its own balance sheet. The financial sponsor invests through a nonrecourse vehicle whose only claim is the SPV's equity and bears no such loss, so $\lambda_F = 0$.[1]

[1]This is the economic content of the sponsor classification used in the empirical work. A contractor's captive investment arm is classified operating; a developer-investor that subcontracts construction is classified financial. The former's project equity is a cost of sales for a business that survives the SPV; the latter's is not. Without $\lambda_O > \lambda_F$, both types borrow to the ceiling, leverage does not differ across them, and Proposition 5 has no content.

Distress occurs with probability $q(D)$, with $q' > 0$ and $q'' > 0$. Sponsor $j \in \{O, F\}$ solves

$$\max_{D \in [0,\, P]} \; (\rho - r_d)\, D \;-\; \mathbf{1}\{j = O\}\, \lambda\, q(D) \qquad \text{subject to} \qquad D \leq \theta_c \Pi, \tag{3}$$

with $E = P - D$. The equilibrium concept is subgame perfection: the sponsor holding control selects the concession, anticipating the financing that follows.

3.3 Participation, Control and Financing

Capital depth and expertise operate through participation; control plays no role in either.

Proposition 1 (Participation and structuring)**.**

(a) There exists $\bar{K}$ such that for $K \leq \bar{K}$ an operating sponsor funds the project alone, and for $K > \bar{K}$ outside equity is required. Projects financed with outside equity are larger.

(b) If the financial sponsor's per-tranche arranging cost satisfies $\kappa_F \leq \kappa_O$, then for a given private contribution its optimal stack uses weakly more instruments.

Part (a) makes the configuration of sponsors a function of project size relative to balance-sheet capacity; preferences over risk play no part in it. A contractor finances alone until the equity a project demands exceeds what it will commit, and past that point outside capital enters whatever its view of the asset. Observing financial money in a deal is therefore informative about size and uninformative about risk-bearing. Part (b) attaches stack complexity to the presence of financial capital, since it follows from arranging cost, which any participant bears, and does not depend on decision rights.

Proposition 2 (Control)**.** *Contract form and leverage are determined by the sponsor holding control. An operator-controlled project with a financial partner therefore exhibits the contract form and the leverage of an operator-controlled project.*

Cash-flow rights and decision rights come apart, and only decision rights bear on the contract and the financing. A financial investor holding a minority position receives its share of whatever the operating sponsor negotiates and finances. An indicator for whether a project has any financial investor therefore pools two configurations the framework says should differ, which attenuates any difference toward zero and conceals it entirely if the two sit on opposite sides of the operator-only benchmark. Thus, participation and control have to be measured separately.

Proposition 3 (Financing)**.** *Suppose* $\lambda q'(0) < \rho - r_d < \lambda q'(\theta_c \Pi)$*. Then*

(a) $D_F = \min\{P,\ \theta_c \Pi\}$ *and* $D_O < \min\{P,\ \theta_c \Pi\}$*, so* $D_F/P \geq D_O/P$*;*

(b) $\mathrm{Var}(E_F/P) < \mathrm{Var}(E_O/P)$*, provided the slack* $(\theta_c \Pi - D_O)/P$ *is uncorrelated with* E_F/P*.*

Both sponsors prefer debt at the margin, since $\rho > r_d$, and they differ in what failure costs them. The operating sponsor's exposure extends beyond its equity to the construction margin and to relationships that outlast the project, so it balances the gain from leverage against a rising probability of distress and stops short of the ceiling. The financial sponsor's exposure is limited to committed equity, so no cost offsets the gain and it borrows to the constraint. Access to credit plays no role in this difference, because both sponsors face the same ceiling $\theta_c \Pi$, set by the lender against the same asset; an explanation resting on financial sponsors obtaining better terms would raise that ceiling for one party, whereas the framework moves both parties along the same ceiling.

Part (b) predicts that financial-led equity shares vary less across projects than operating-only ones. The financial sponsor's equity is a residual left by the lender's advance rate, so it inherits only the variation in the constraint, while the operating sponsor selects its equity and therefore inherits that variation plus its own. Competing accounts of why financial sponsors lever more are silent on dispersion, which is what makes this prediction useful.

3.4 Contract Choice, and What Separates the Four Channels

Proposition 4 (Selection)**.** *A financial sponsor with control strictly prefers the availability concession. An operating sponsor with control is indifferent between contracts on this margin.*

The contract is a financing instrument as well as a device for sharing risk, and its value to a sponsor depends on whether that sponsor is constrained by pledgeability. A party borrowing less than the ceiling permits is indifferent to the ceiling's height, while a party standing at it gains the full present value of the additional advance. Sorting into contract forms is therefore driven by one side of the market. The framework predicts that financial control moves the contract and that operator control leaves it where the grantor's preferences and sector convention put it.

Proposition 5 (Discrimination)**.** *The leverage gap between configurations is larger under the availability concession than under revenue risk.*

All four channels imply that financial sponsors appear in availability concessions, so their presence there is uninformative. They differ in what they imply for leverage, and the difference lies in the shape of the gap across contract forms as well as in its sign. Capital depth makes no signed prediction, since the ability to fund with equity and the incentive

to spread a fund across assets work in opposite directions. Expertise predicts a gap that does not vary with contract form, since a sponsor able to pledge more can do so under any contract. Risk aversion predicts a gap smallest under the availability contract, because an investor averse to variance economizes less on equity once variance is absent. Undiversified distress cost predicts a gap largest there, because only one party is constrained by the ceiling that contract raises. Comparing the gap under the two contract forms therefore separates the three signed predictions. A gap of equal size under both forms would mean either that the ceiling does not bind for financial sponsors under revenue-risk contracts, in which case both types are interior and the framework predicts no gap under either contract, or that the distress-cost channel is not the operative one.

In the empirical sections, I take these predictions in order. In Section 5, I test Remark 1 on the two public instruments and report the three architectures as outcomes. In Section 6, I test Proposition 1 on where financial capital participates and how many instruments it uses, Proposition 2 on the divergence between participation and control, Proposition 4 on contract choice, Proposition 3 on leverage and on the dispersion of equity shares, and Proposition 5 on the shape of the leverage gap across contract forms, which separates the four channels. Every sign was fixed before the corresponding regression was run. Two results reported below have no prediction attached because the framework makes none: concession length, and the public money a project receives.

Boundaries. The framework takes K, the public contributions, and the assignment of control as given. It characterizes which sponsor finances which contract in what manner, and is silent on why a grantor offers a particular contract and on how sponsors and projects are

matched.

4 Data

To my knowledge, no existing database decomposes the P3 capital stack by funding source at the project level. Commercial platforms such as IJ Global, Infralogic and SDC Platinum record aggregate deal values, which is the equivalent of studying corporate capital structure while observing only the size of the balance sheet. In this section, I describe the dataset built for this paper. It records, for each project at financial close, private equity, private borrowing by instrument, private activity bonds, federal credit, federal grants, and state and local contributions, together with the contract terms that govern the project's revenue and the identity of the private sponsors.

4.1 Sources and Sample Construction

The dataset records 1,815 U.S. infrastructure projects, assembled by cross-referencing seven sources. The Federal Highway Administration P3 project list and the Build America Bureau records of TIFIA and PAB awards are authoritative for surface transportation but cover no other sector. InfraPPP extends coverage to water, energy and social infrastructure. Public Works Financing, a trade publication tracking project capital structures since the early 1990s, has the richest financing detail and incomplete project coverage. The Water Design-Build Council handbooks and the Texas Department of Transportation alternative-delivery list fill in two segments the others underrepresent, and the University of Maryland US Major Transportation Projects Database adds large transport projects and their schedules. I merge

the sources in descending order of definitiveness, so that the most reliable identifiers anchor the sample before less standardized ones are matched to it.

Assembling these sources is more than a merge, for two reasons. First, project identifiers are not standardized, and the same project appears under different names, locations and attribute formats across sources. Deduplication therefore uses a multi-stage procedure that combines large language model screening with manual verification of project documents, described in Appendix A2. Second, and more consequentially, no source decomposes the capital stack. I hand-collected every financing figure in this dataset from primary sources (sponsoring-agency disclosures and financial close summaries, sponsor press releases, trade and general press coverage, and, for projects that issued them, bond official statements filed on EMMA) and stored each with a verbatim quotation from the source and the source URL, so that each number in the tables that follow can be traced to the document it came from. Appendix Table A2 lists the collection stages and what each contributed.

Table 3 reports the construction of the analysis sample. Of the 1,815 projects, 796 are P3s by delivery mode, and 615 of those are privately financed: 585 use a delivery mode that includes private financing, and 30 are lease-operate-maintain concessions with an upfront concession fee. I count a fee lease as privately financed because the fee is raised as equity and debt at the project level. For example, the Indiana Toll Road concession was financed with $748 million of equity and $3,030 million of debt. Restricting to projects that reached financial close or began construction, and for which a private capital total is recorded, leaves **392 projects**, which form the analysis sample; 22 of them are fee leases.

4.2 What the Dataset Measures

Each project carries over forty variables in four groups. *Contract terms* record the delivery mode, the concession type and its length, and the lifecycle stages bundled. *Timeline and cost* record the financial close date, construction start and duration, and total capital cost. The *capital stack* is decomposed into eleven components: federal grants to state and to local recipients, federal credit to public and to private borrowers, state and local cash contributions, municipal bonds, private equity, private activity bonds, private taxable bonds, private bank loans, and other private borrowing. *Sponsors* record every private entity named in the project documents, each matched to firm-level data and typed as financial or operating.

Three of these features are absent from commercial data, and the analysis rests on all three. First, the private contribution is separated into equity and debt, and the debt into subsidized and market-rate instruments, so leverage is measurable. Second, public money is recorded by level and by type, so the distinction between a grant and a credit subsidy is measurable. Third, contract design is recorded alongside financing, so risk allocation can be read off the contract without inference from outcomes.

4.3 Two Layers of Measurement

The data support two layers of measurement, and conflating them would misstate what can be asked of which projects. The *first layer* requires only project totals: how much private capital participates, what the public contributes, what contract governs the revenue, and how large the project is. All 392 projects support these questions. The *second layer* requires the private capital to be decomposed into instruments, and 309 projects support it. The

distinction matters because a blank instrument field means different things in the two layers. Where the private stack is decomposed, a blank private activity bond entry records that the project used no such bonds, whereas where it is not, the same blank records that the split was never disclosed. Treating undisclosed as zero would understate borrowing and overstate equity precisely among the projects that report least, so I use instrument-level variables only within the second layer.

A further restriction applies to leverage. Among the 309 projects with a decomposed stack, 156 report both equity and debt, and the remainder sit at corners, with either no project-level debt at all or no sponsor equity. Leverage is a meaningful continuous ratio only in the interior case, and in Section 5 I show that the corners are distinct financing architectures and cannot be read as extreme values of one distribution.

4.4 Classifying Sponsors

I match every private entity recorded for a project to firm-level data and classify it as financial or operating on the basis of its own business; its role in the individual deal does not enter the classification. A firm is financial if its own investor type is an infrastructure fund, asset manager, private equity or buyout vehicle, sovereign wealth fund, or similar, or if its own industry is financial services. This rule places developer-investors that subcontract construction, such as Plenary and Meridiam, among financial sponsors, while a contractor's captive investment arm, such as Skanska Infrastructure Development, is classified operating even though it holds project equity. An operating company owned by a private equity fund is classified operating, since the project's counterparty is a builder.

I then assign projects to three configurations. *Operating only* projects record no financial sponsor. *Financial partner* projects contain a financial investor other than the lead. *Financial-led* projects have a financial investor as lead sponsor, where the lead is the largest equity holder and, absent recorded shares, the first-listed entity. I find that on the 41 projects where explicit equity percentages are available for two or more partners, the first-listed entity is the largest holder in every case once name variants are resolved, which supports the ordering rule.

The source material imposes two limitations. First, sponsor lists are only as complete as the underlying documents, so a project recording a single entity may have had partners the source did not name, and the financial-partner category is a lower bound. Second, documentation rises with project size. For example, a $500 million toll road leaves an official statement and a Value for Money analysis, whereas a $30 million water plant often leaves only a press release. The decomposed layer therefore over-represents large projects, and results that rest on it should be read as applying to that part of the market.

5 Private Capital in U.S. Infrastructure

In this section, I describe how private capital enters the capital stack of a P3 and how the two forms of public support sit alongside it. I begin with the empirical specification used throughout the paper. I then document that private money arrives in three distinct financing structures, and finally I examine how a federal grant and a federal credit subsidy each appear in the stack. In Section 6, I then ask what changes when the private investor is a financial firm.

5.1 Empirical Specification

All estimates in the paper are cross-sectional project-level regressions of the form

$$Y_i \;=\; \alpha \;+\; \beta' X_i \;+\; \gamma \ln K_i \;+\; \delta_{s(i)} \;+\; \eta_{d(i)} \;+\; \varepsilon_i, \tag{4}$$

where Y_i is an outcome for project i, X_i is the vector of explanatory variables of interest, $\ln K_i$ is the log of total project cost, and $\delta_{s(i)}$ and $\eta_{d(i)}$ are sub-sector and decade fixed effects, the sub-sector being one of fifteen asset types (road, transit, airport, student housing, and so on) within the three sectors. I cluster standard errors by state, since P3 enabling legislation, procurement practice and project pipelines are set at the state level. In Section 6, X_i consists of two indicators for the sponsor configurations that contain financial capital, so that each coefficient measures the difference from an operating-only project of the same size, of the same asset type, in the same decade. Robustness specifications add controls for the number of lifecycle tasks bundled and the number of private entities recorded, and the leverage comparison is also estimated separately by contract form; I report them alongside the baseline in the same tables. Where a split sample is small, I absorb sector rather than sub-sector and say so in the table.

The size control deserves comment, because it changes how the estimates should be read. Proposition 1(a) implies that financial capital enters where the equity requirement exceeds what a contractor will commit alone, so project size is one of the channels through which the sponsor configuration is determined. For example, if financial investors enter only projects above a size threshold, a size control absorbs part of the very selection the framework describes. Controlling for size therefore removes part of the effect of interest,

and the estimates in Section 6 are likely conservative. Where the prediction concerns the composition of the private stack (the number of instruments it uses), the specification holds private capital fixed, and I report both versions.

It is worth noting up front that the estimates in this paper cannot be viewed as causal. Sponsors choose projects and projects attract sponsors, so the coefficients describe which projects have which sponsors and which contracts, and they do not say what would happen if a sponsor were reassigned. However, the setting offers one advantage over most work on financial ownership. The object of interest, the allocation of demand risk, is written into the contract at financial close, so it can be measured directly and need not be inferred from realized outcomes. The descriptive content of the estimates is therefore sharper than their identification.

5.2 Private Capital Arrives in Three Structures

Among the 309 projects whose private stack is decomposed into instruments, I find that private capital arrives in three distinct financing structures, each of which corresponds to a corner or interior solution of the financing problem in Section 3. Under *corporate balance-sheet* financing, the private total sits entirely in equity and the project carries no project-level debt; 74 projects, with a median cost of $64 million, are financed this way. Under *conduit bond* financing, the private total sits entirely in debt and there is no sponsor equity; 79 projects, with a median cost of $110 million, take this form. These are predominantly $501(c)(3)$ structures, concentrated in student housing, in which a nonprofit issuer raises tax-exempt bonds covering the full cost and the developer acts as a fee-earning contractor with no equity

stake. Under *project finance*, both equity and debt are present; 156 projects, with a median cost of $500 million, are financed this way. Project finance thus appears to be the architecture of the large project, and the two corners the architectures of the small one.

Pooling the three structures into one leverage distribution would be a measurement error, because the two corners carry leverage values that reflect no capital structure choice of the kind the framework describes. For example, a student-housing project financed with a single $501(c)(3)$ bond issue has leverage of one by construction, while a design-build-finance project funded from a contractor's balance sheet has leverage of zero. I therefore treat the architecture as an outcome in its own right and confine leverage to the interior case, where the median is 0.77 across the 156 projects reporting both equity and debt. This figure is high by the standard of a corporate balance sheet and ordinary for project finance, in which a single asset with a contracted revenue stream and no recourse to a sponsor routinely supports ratios of this order (Esty, 2002). The corporate comparison is in any case loose, since an SPV holding one asset is not a firm, and the relevant benchmark is the rest of the project finance market.

5.3 What the Public Sector Provides

The framework distinguishes two routes by which public support reaches the capital stack. A grant enters the accounting identity in equation (1) directly and lowers the private requirement one-for-one, whereas subsidized credit operates on price, lowering the blended cost of the private stack without relaxing the borrowing constraint. If this distinction holds in the data, a project with access to subsidized credit should carry a larger private share of capital, while

a project receiving a grant should carry a smaller one.

Table 4 reports the estimates for the two channels side by side. I find that projects with access to a private activity bond or a federal loan carry a private share of capital 6.6 percentage points higher than projects without such access, statistically significant at the 1% level, which amounts to about 8% of the sample mean private share of 0.84. In contrast, a one percentage point increase in the federal grant share of capital expenditure is associated with a 0.96 percentage point decline in the private share. The same federal dollar is therefore associated with more private capital when it takes the form of a credit subsidy and with less when it takes the form of a grant, consistent with the framework's distinction between the price and quantity channels.

However, the grant coefficient should not be read as a behavioral response, because it is bounded by an accounting identity. Since the capital stack shares sum to one, regressing the private share on the grant share returns minus one plus whatever the other public components absorb, so the coefficient is a decomposition, and the informative question is which component absorbs the grant. In Table 5, I place the private share and the state and local share on the left-hand side in turn. In column (1), the private share falls by 0.96 percentage points per point of grant share, while in column (2) the state and local share is statistically unchanged, with a coefficient of -0.077 that is not significant at conventional levels. These estimates suggest that grant money displaces private capital and leaves local contributions essentially untouched. I describe this pattern as incidence, since the regression records where a grant dollar lands in the stack, and I do not interpret it as crowd-out. Overall, the two forms of federal support leave opposite signatures in the capital stack, and in Section 6 I ask whether the identity of the private investor changes any of this.

6 What Private Financial Capital Changes

In this section, I examine what changes when the private investor is a financial firm. The framework in Section 3 yields two sets of predictions. Capital depth and expertise operate through participation, so a financial investor should appear in larger projects and divide a given contribution across more instruments whether or not it leads the consortium (Proposition 1). Contract choice and leverage are set by the sponsor holding control, so a financial investor should take less contracted demand risk and carry more leverage only when it leads (Propositions 2 through 5). Throughout, the relevant distinction is therefore between a financial investor that leads the consortium (financial-led) and one that participates under an operating lead (financial partner), and each is compared with a project whose sponsors are operating firms only. I begin with where financial capital sits, then turn to instruments, contracted risk, leverage and the dispersion of equity shares, and finally to the public money financial sponsors receive.

6.1 Where Financial Capital Sits

Proposition 1(a) predicts that outside equity enters where a project's equity requirement exceeds what a contractor will commit alone, so financial capital should be concentrated in larger projects. The raw descriptive statistics in Table 6 are consistent with this prediction. I find that the median project costs $117 million where the sponsor group is operating only, $460 million where a financial partner is present, and $400 million where a financial investor leads, so the two financial configurations sit in projects roughly three and a half to four times the size of operating-only projects. Financial capital is also concentrated in the project-finance

architecture, which accounts for 29.5 percent of operating-only projects against 70.3 percent of financial-partner and 67.7 percent of financial-led projects, while conduit-bond structures move in the opposite direction, from 23.6 percent of operating-only projects to 5.4 and 12.3 percent. Figure 7 reports the full capital stack behind these figures, source by source, and Figure 8 places them in time. Ninety percent of projects with a recorded financial close closed in 2005 or later, and the share with a financial investor rose from fewer than one in ten before 2000 to more than one in four after 2010, where it has since remained.

In Table 7, I estimate the architecture differences from equation (4), holding size, subsector and decade fixed. I find in column (2) that both configurations containing financial capital are more likely to use project finance than operating-only projects, by 23.3 and 22.6 percentage points for the financial-partner and financial-led configurations against an operating-only rate of 29.5 percent; both estimates are statistically significant at the 5% level or better. Because the three architectures exhaust the decomposed sample, a higher project-finance share is by construction a lower share of the other two structures, and in the raw shares reported above the offset falls on the conduit-bond structure. Column (3) repeats the project-finance comparison counting only debt that is unambiguously at the project level (private activity bonds, federal credit and project bonds) and excluding bank and other borrowing, which may sit on a sponsor's own balance sheet. The financial-led estimate survives at 15.5 points, whereas the financial-partner estimate falls to 6.9 points and is no longer statistically significant. These results suggest that the architecture result is secure for financial control and weaker for participation alone.

6.2 Financial Capital Uses More Financing Instruments

Proposition 1(b) predicts that a sponsor facing lower arranging costs divides a given private contribution across more instruments, and because the mechanism is arranging cost, the prediction applies whether or not the financial investor holds control. I test this prediction in Table 8 on the projects whose private stack is decomposed. Because the prediction concerns the composition of the stack, the relevant specification holds private capital fixed, which column (2) does; column (1) holds project size fixed instead, and column (3) holds both fixed. I find that financial-partner projects use 0.47 more instruments and financial-led projects 0.29 more, holding private capital constant, against an operating-only mean of 1.6, so the two configurations add between a sixth and a little under a third to the instrument count. Both estimates are statistically significant at the 1% level and are stable across the size controls. That both configurations show the effect is what the framework predicts, since expertise follows from arranging cost and travels with participation. In sum, financial capital appears to bring structuring expertise to a project whether or not it holds control.

6.3 Financial Control and the Allocation of Demand Risk

Proposition 4 predicts that a financial sponsor with control prefers the availability-payment concession, under which the public sector bears demand risk, while an operating sponsor is indifferent on this margin. Figure 9 shows the three contract forms across the three sponsor configurations, and the raw pattern is consistent with the prediction. Among projects with a recorded concession, 54.2 percent of financial-led projects are availability-payment arrangements, against 22.5 percent of operating-only projects, while full demand risk moves

the opposite way, from 68.1 percent of operating-only projects to 37.3 percent of financial-led projects.

In Table 9, I estimate these differences from equation (4), holding size, sub-sector and decade fixed. I find that financial-led projects are 23.0 percentage points more likely to carry an availability payment (column 1) and 22.8 points less likely to bear full demand risk (column 2), about a third of the operating-only rate of 68.1 percent, and that the index of demand risk borne privately falls by 0.46 on a scale that runs from one to three (column 3). Relative to the operating-only base rate of 22.5 percent, the availability estimate implies that financial control roughly doubles the probability of an availability-payment contract. Because the sub-sector fixed effects hold the asset type fixed, these are comparisons among roads, among transit facilities, or among student-housing projects, so the result cannot be a matter of financial investors favoring asset types that are availability-paid by nature. The estimates condition on a recorded concession, so a zero records a different contract type, and a blank contract field is excluded rather than read as a zero. All three coefficients exceed three and a half times their standard errors, and all three carry the sign that Proposition 4 predicted before the regression was run.

Financial partners follow the operating pattern. Proposition 2 predicts that the contract form is set by the sponsor holding control, so a financial partner under an operating lead should exhibit the contract form of an operating-only project. The estimates in Table 9 bear this prediction out. In contrast to the financial-led estimates, I find that the financial-partner coefficient on the availability indicator is -0.113 and statistically indistinguishable from zero, and that the coefficient on full demand risk is likewise indistinguishable from zero.

In raw terms, 76.5 percent of financial-partner projects carry full demand risk, a higher share than operating-only projects, and 17.6 percent are availability arrangements. The bottom row of Table 9 reports a test of whether the partner and led coefficients are equal, which rejects equality at the 1% level on every risk outcome. This equality test is the most precisely estimated result in the paper, and it has a specific implication. Whatever financial capital does to risk allocation appears to operate through control, since presence alone leaves the contract where an operating sponsor would put it, and a treatment story in which financial money changes a project simply by arriving would not produce this pattern. The result also carries a measurement warning for studies that observe only whether a financial investor is present. An indicator for whether a project has any financial investor pools two configurations that sit on opposite sides of the operating-only benchmark, which attenuates the difference toward zero and can conceal it entirely.

Concession length reflects contract mix. Financial-led projects have somewhat shorter concessions unconditionally, by about two years at the median (33 against 35 years, Table 6), although the gap is not statistically significant at conventional levels once size, sub-sector and decade are held fixed (Table 10, column 1). In the same table, I ask whether any gap survives holding contract form fixed, and I find that it does not. Within availability deals the financial-led coefficient is +3.8 years and within demand-risk deals it is +0.6 years, and neither is distinguishable from zero. The unconditional gap therefore appears to be composition, since availability concessions are shorter and financial-led sponsors sit in them. The conditional cells are small (32 financial-led and 46 operating-only projects among availability deals), however, so these are low-powered nulls and the columns cannot demonstrate equality. The

median lengths make the same point more directly: within availability deals, 30 years for financial-led projects against 25 for operating-only projects; within demand-risk deals, 50 years against 40, since the brownfield leases that financial investors lead are long-dated. In neither contract form are financial-led concessions shorter. Financial partners' concessions, in contrast, are longer, by 11.6 years overall and 8.8 years within availability deals, which is consistent with the configuration in which they appear (large, long-dated projects whose equity requirement exceeds what a contractor will commit alone).

Robustness to delivery mode and documentation. The primary alternative explanation for the availability result is that financial sponsors simply use the most comprehensive delivery mode and that such modes happen to be availability-based. In Table 11, I address this concern by controlling for the number of lifecycle tasks bundled in the contract, which leaves the financial-led estimate at 22.2 points (column 2). A second concern is documentation: a project with more private entities recorded may simply be better documented, and better-documented projects may be the ones with an availability payment on file. Controlling for the number of private entities recorded leaves the estimate at 22.0 points (column 3), and both controls together leave it at 20.9 points (column 4); every estimate remains statistically significant at the 1% level. I therefore find no evidence that the result reflects delivery-mode composition or documentation intensity. Overall, the availability result is robust to how projects are bundled and to how well they are documented, and, because the baseline already absorbs the asset type, to the composition of asset types across sponsor configurations.

6.4 Financial Control and Leverage

The results so far show that financial sponsors take less contracted risk. However, Proposition 3(a) predicts that they do not take less risk overall, because a sponsor whose exposure is limited to its equity borrows to the lender's ceiling while an operating sponsor, which also stands to lose the construction margin and its relationships, stops short of it. I test this prediction in Table 12 within the project-finance architecture, the only sample in which leverage is a meaningful ratio. I find in column (1) that financial-led projects run leverage 8.8 percentage points higher than operating-only projects, significant at the 5% level, which is about 13% of the operating-only mean of 0.68; adding an availability-payment indicator as a control leaves the estimate at 7.4 points (column 2). Column (4) repeats the comparison using only debt that is unambiguously at the project level, and the estimate survives at 13.5 points, significant at the 5% level. Financial-partner projects show no difference in any column, again consistent with a mechanism that operates through control. Table 13 reports the composition of the private stack behind these ratios.

I next ask where in the contract space the leverage gap sits, since its shape across contract forms separates the candidate mechanisms. The framework identifies four differences between sponsor types that could produce such a gap, and Proposition 5 shows that they are distinguishable by the shape of the gap across contract forms. Capital depth makes no signed prediction, and expertise predicts a gap under every contract, since a sponsor able to pledge more can do so from any asset. Risk aversion predicts a gap that is smallest under the availability contract, whereas undiversified distress cost predicts a gap that is largest there, because only one party is constrained by the ceiling that contract raises.

In Table 14, I split the sample by contract form and find that the gap is concentrated under the availability contract. Under availability concessions the financial-led coefficient is +0.194 and significant at the 5% level (column 1), and it is unchanged at +0.196 once the number of lifecycle tasks bundled is controlled for (column 2), whereas under demand-risk concessions it is +0.050 and indistinguishable from zero (column 3). The underlying means point the same way. Leverage runs between 0.67 and 0.72 in every sponsor-by-contract cell except financial-led availability deals, where it is 0.86 (Figure 10 shows the cells). The point estimates carry the sign that undiversified distress cost predicts and that Proposition 5 fixed in advance, and the opposite of the sign risk aversion predicts. However, the two split-sample estimates are not formally tested against each other, and the availability cell is small, so these estimates cannot reject a gap of equal size under both contracts, which is what expertise predicts.

Two further features of the estimate qualify this reading. The availability cell contains 22 financial-led projects among 45, so the adjudication rests on a modest sample, and the demand-risk estimate, while close to zero, is imprecise enough that a gap of several points there cannot be excluded. While these results are therefore only suggestive, the point estimates favor the distress-cost channel over the alternatives the framework considers.

6.5 Equity Shares Are Less Dispersed Under Financial Control

Proposition 3(b) makes a prediction about dispersion that competing accounts of the leverage gap do not. If the financial sponsor's equity is a residual left by the lender's advance rate, it inherits only the variation in the constraint, whereas the operating sponsor's equity, which

the sponsor selects, inherits that variation and its own. Financial-led equity shares should therefore vary less across projects than operating-only ones.

I find that within the project-finance architecture the standard deviation of the equity share is 0.158 across 44 financial-led projects and 0.233 across 85 operating-only projects, a variance ratio of 2.17. The prediction is directional, and the one-sided variance-ratio test it calls for rejects equality at $p = 0.003$; the two-sided p-value is 0.006. However, the equity share is bounded and non-normal, so I also report robust tests, and they agree with the variance-ratio test: Levene's test gives $p = 0.011$, the 10 percent trimmed version $p = 0.013$, and the median-centred Brown-Forsythe version $p = 0.025$. The means differ in the same direction, 0.204 against 0.316. The difference in dispersion is consistent with a binding constraint, and it survives every test reported here at the 5% level, although on modest samples of 44 financial-led and 85 operating-only projects.

6.6 What Financial Sponsors Obtain

The results to this point establish that financial-led sponsors take materially less contracted demand risk. A natural further question is whether they also obtain a larger share of the subsidized credit the federal government supplies, and the answer, as shown in Table 15, is that within an asset type they do not. In raw terms, use of private activity bonds is similar across sponsor configurations: among projects whose stack is decomposed, 41.8 percent of those with a financial investor use them against 39.8 percent of operating-only projects. Among the projects that record subsidized debt, the subsidized share of private capital is 17.1 percentage points higher for financial-led projects when sector and decade are held fixed,

statistically significant at the 5% level (column 1). However, once the asset type is held fixed through sub-sector fixed effects, the estimate falls to 14.3 points and is no longer statistically significant at conventional levels (column 2), and the bundling and sponsor-count controls leave both estimates where they are (columns 3 and 4). The sample is small, 81 and 78 projects, so these are imprecise estimates, and the honest reading is that the data do not show financial control commanding a larger share of subsidized credit within an asset type. Financial-partner projects show no difference in any column.

Federal credit is the one instrument on which the raw pattern differs. It is lent to the private party in 18.7 percent of projects with a financial investor against 6.5 percent of operating-only projects, and in untabulated regressions the gap survives controls for size and size quintiles, industry fixed effects, and restriction to projects above the eligibility threshold, so it does not appear to be an artifact of scale. However, the pattern rests on 31 borrowers in the entire sample, of which 17 have a financial investor, and federal loans to public borrowers show no such tilt. I therefore report it as a descriptive regularity, with denominators shown in Table 16, and do not test it, since thirty-one events cannot support a sponsor-level inference.

The support associated with financial control is therefore contractual, and the distinction from budgetary support matters for how it is counted. A grant is appropriated and visible in a budget, while a thirty-year availability commitment is an obligation that public accounting has only recently begun to recognize, so the form of support financial sponsors obtain is less visible in fiscal statistics than a grant of comparable value. Overall, the results of this section suggest that financial control changes the kind of risk a project's private party bears, with less of the demand risk written into the contract and more of the financial risk the sponsor creates itself, without a larger share of subsidized credit once the asset type is held fixed.

7 Conclusion

Private financial investors in U.S. public infrastructure hold the end of the concession from which demand risk has been removed and the levered end of the capital structure, and both patterns appear only where they control the consortium. Where a construction or facilities firm leads and the fund holds a minority position, the contract and the leverage are the construction firm's. What financial control changes is therefore not the level of risk borne but its kind: less of the demand risk written into the contract, more of the financial risk the sponsor creates itself.

The gap between the two configurations carries a lesson beyond this setting. Research on financial ownership usually observes who owns an asset rather than what the owner agreed to bear, and reads risk-bearing backwards from what happened afterwards. Here the two configurations sit on opposite sides of the operating-only benchmark, so an indicator for the presence of a financial investor recovers approximately nothing. Where control cannot be separated from participation, a null is not evidence of no effect.

The sorting also changes how the contract itself should be read. The P3 design literature treats the allocation of risk as a choice the grantor makes to sharpen incentives. The evidence here suggests it is partly settled by which private party is available to fund the equity: a contractor finances alone until the requirement exceeds what its balance sheet will commit, and past that point outside capital enters, bringing with it a preference for the contract that pledges most. Public retention of demand risk is then in part a by-product of project scale rather than a considered allocation, which is a different object from the one the design literature models.

For policy the implication is that risk allocation and subsidy design are separate levers, and only one of them sorts on the identity of the private partner. Subsidized credit reaches financial and operating sponsors alike; the contract does not. And the support that travels with financial control is the kind least visible in public accounts. A thirty-year availability commitment is an obligation that public accounting has only recently begun to recognize, so a program justified by risk transfer may deliver least of it exactly where the private counterparty is most practised at financing, and may do so without appearing in a budget.

Two questions follow. Whether the risk transfer holds ex post is testable with contractual outcomes—renegotiation, termination and equity sales—which I collect here for road projects and which would need extending to the rest of the sample. And whether the sorting documented here is efficient is a question this evidence cannot settle: a government may rationally prefer to retain demand risk, and knowing whether it pays the right price for doing so requires the realized cost of these contracts rather than their terms at financial close.

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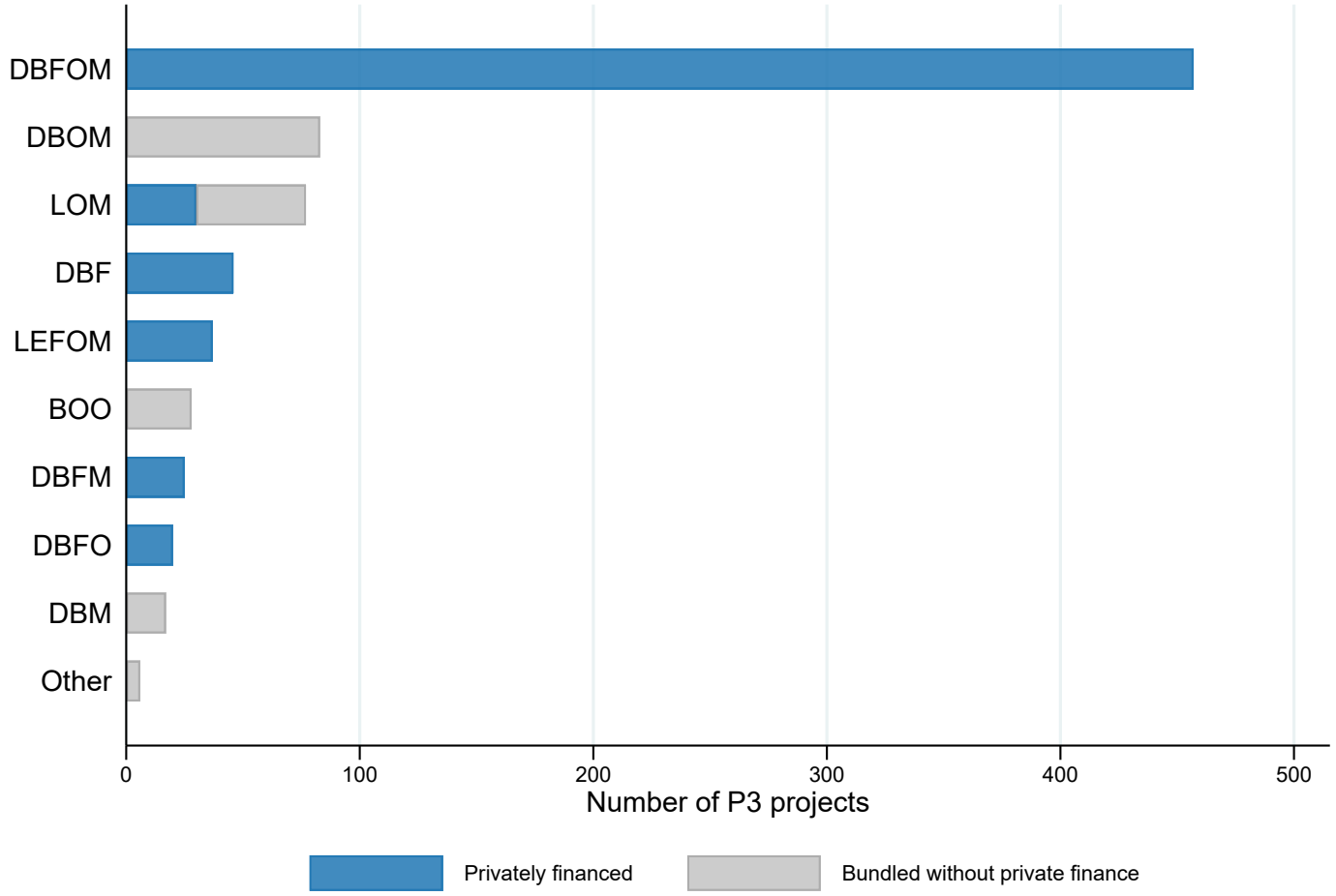
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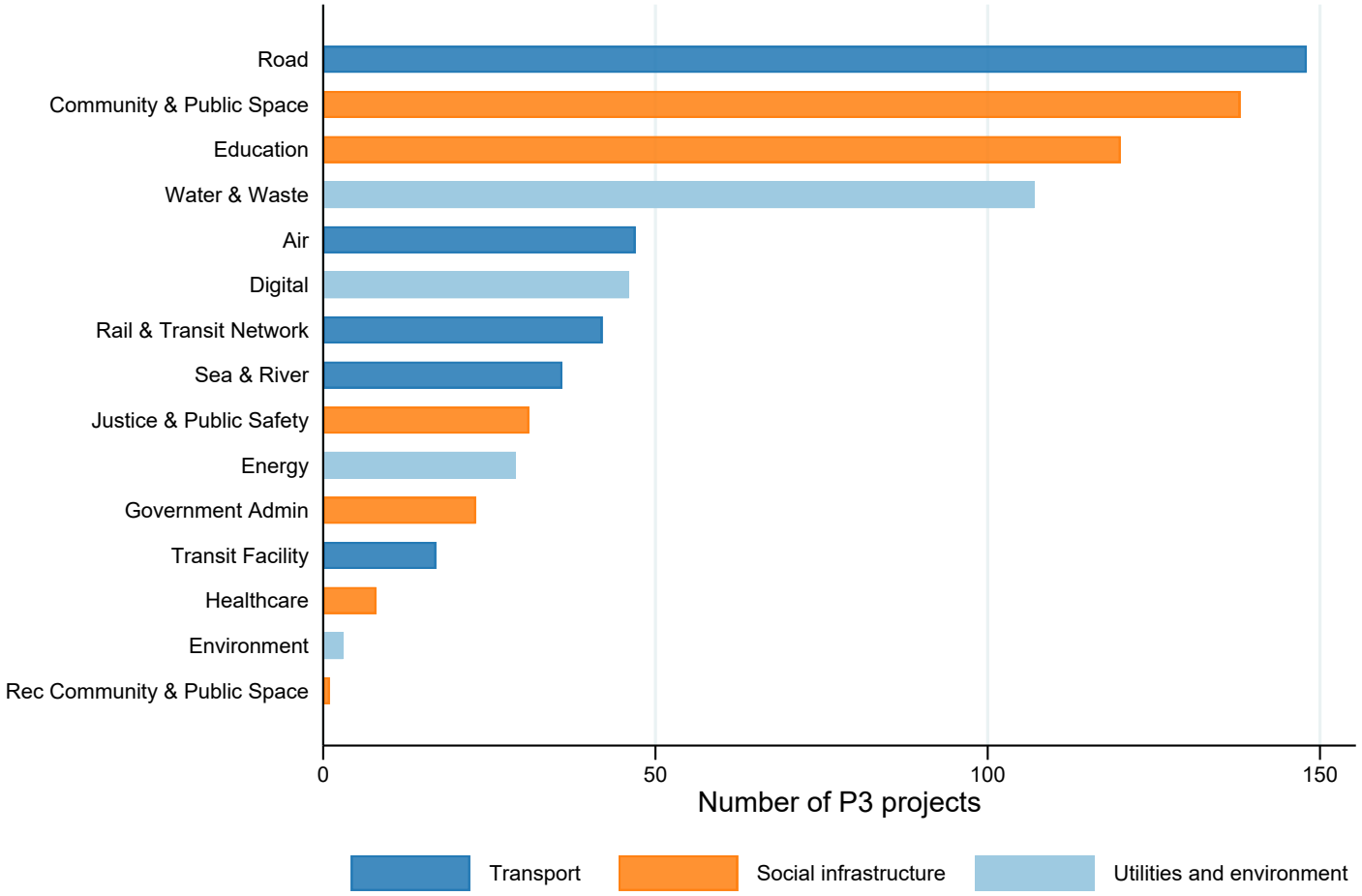
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Figure 1: P3 projects by delivery mode



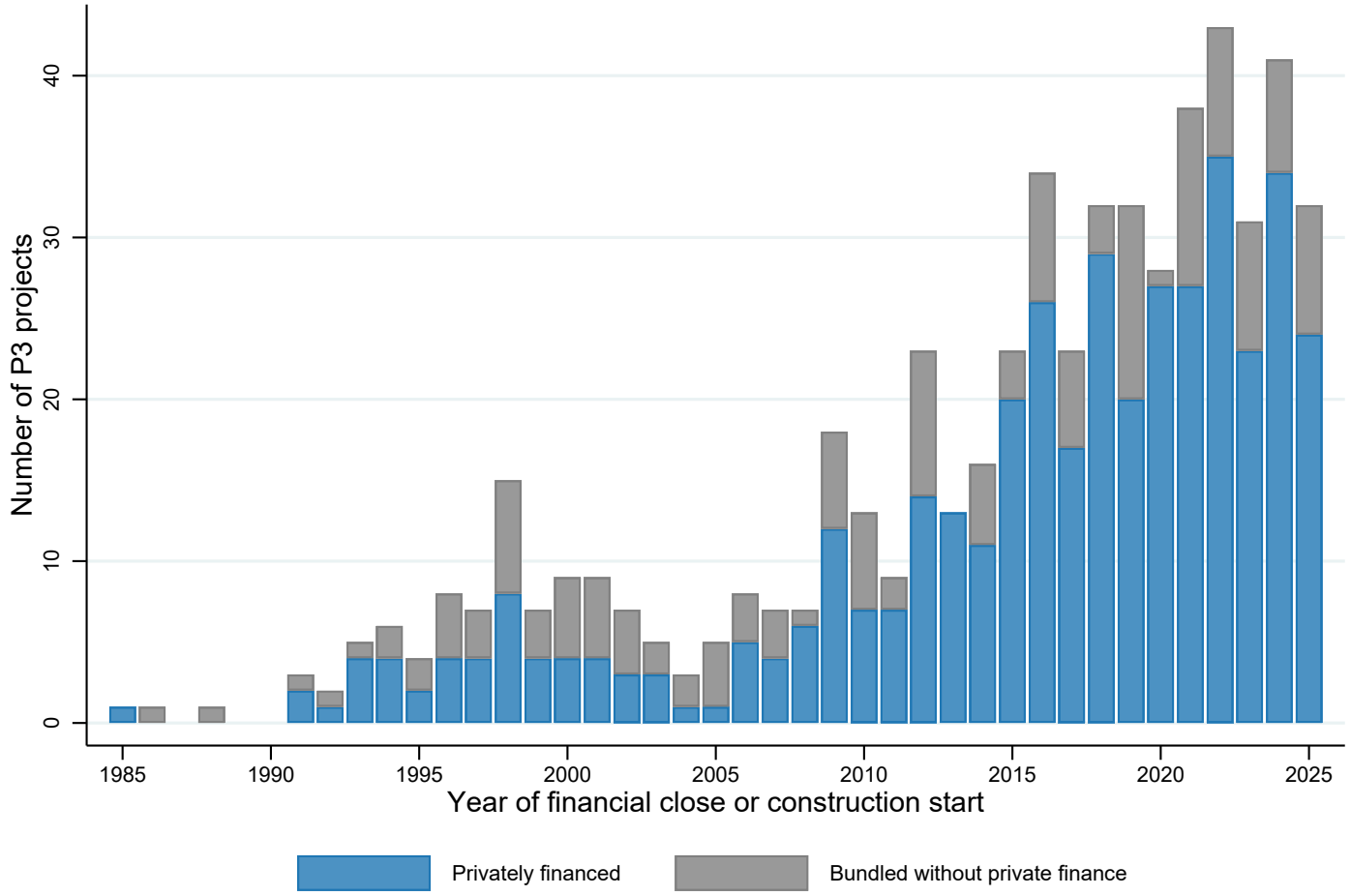
Note: D=design, B=build, F=finance, O=operate, M=maintain, L=lease, BOO=build-own-operate.
Source: Authors' compilation from FHWA, BAB, InfraPPP, Public Works Financing, WDBC handbooks, TxDOT and the US Major Transportation Projects Database.

Figure 2: P3 projects by sector and subsector



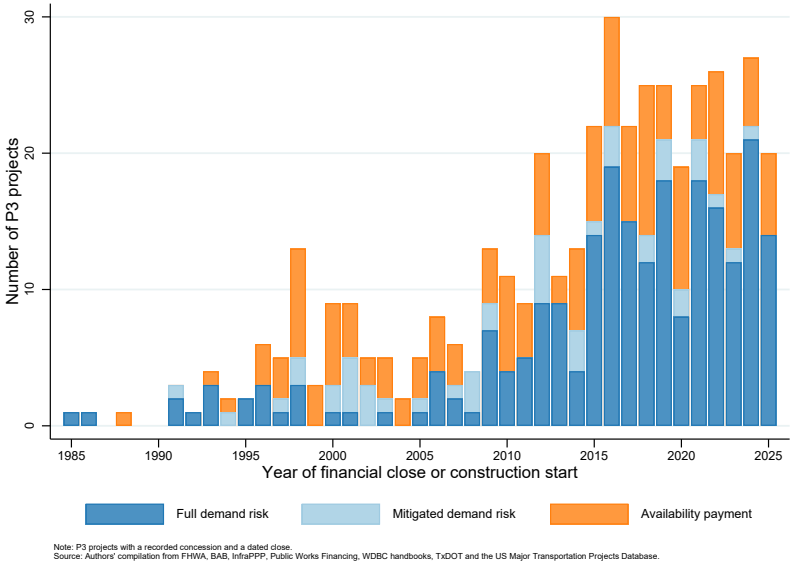
Note: Subsectors follow the project taxonomy described in the appendix.
Source: Authors' compilation from FHWA, BAB, InfraPPP, Public Works Financing, WDBC handbooks, TxDOT and the US Major Transportation Projects Database.

Figure 3: P3 activity over time, with and without private financing

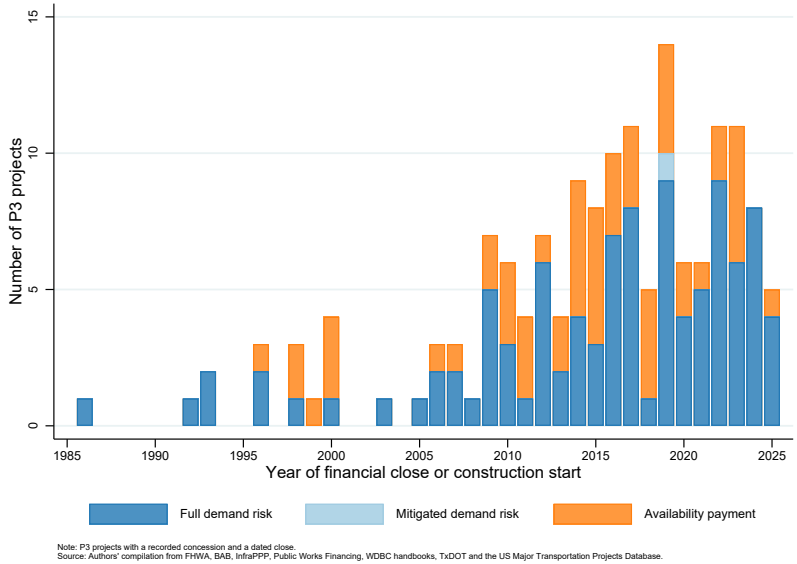


Note: P3 projects with a dated financial close or construction start.
Source: Authors' compilation from FHWA, BAB, InfraPPP, Public Works Financing, WDBC handbooks, TxDOT and the US Major Transportation Projects Database.

Figure 4: Concession type over time

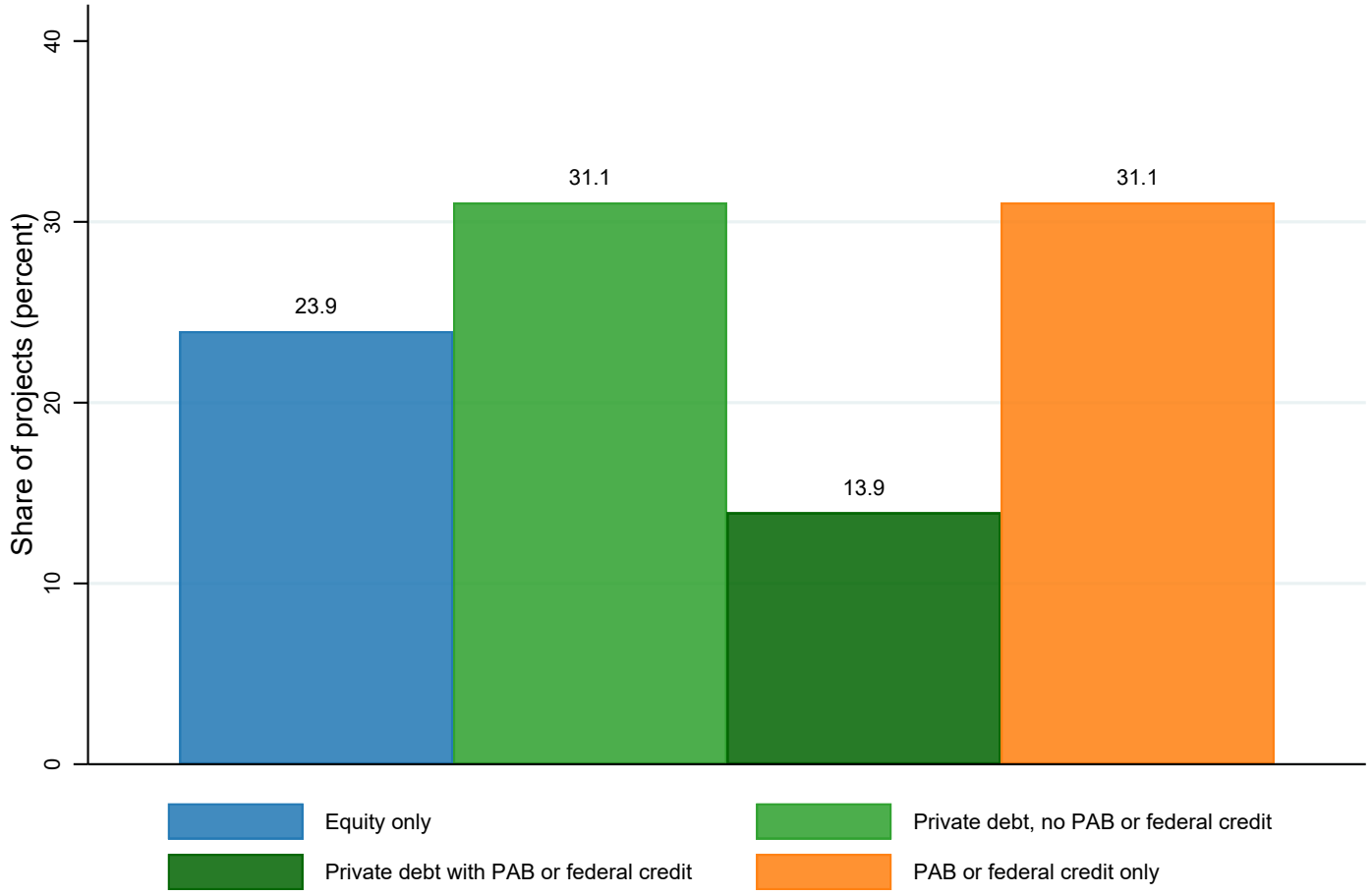


(a) All sectors



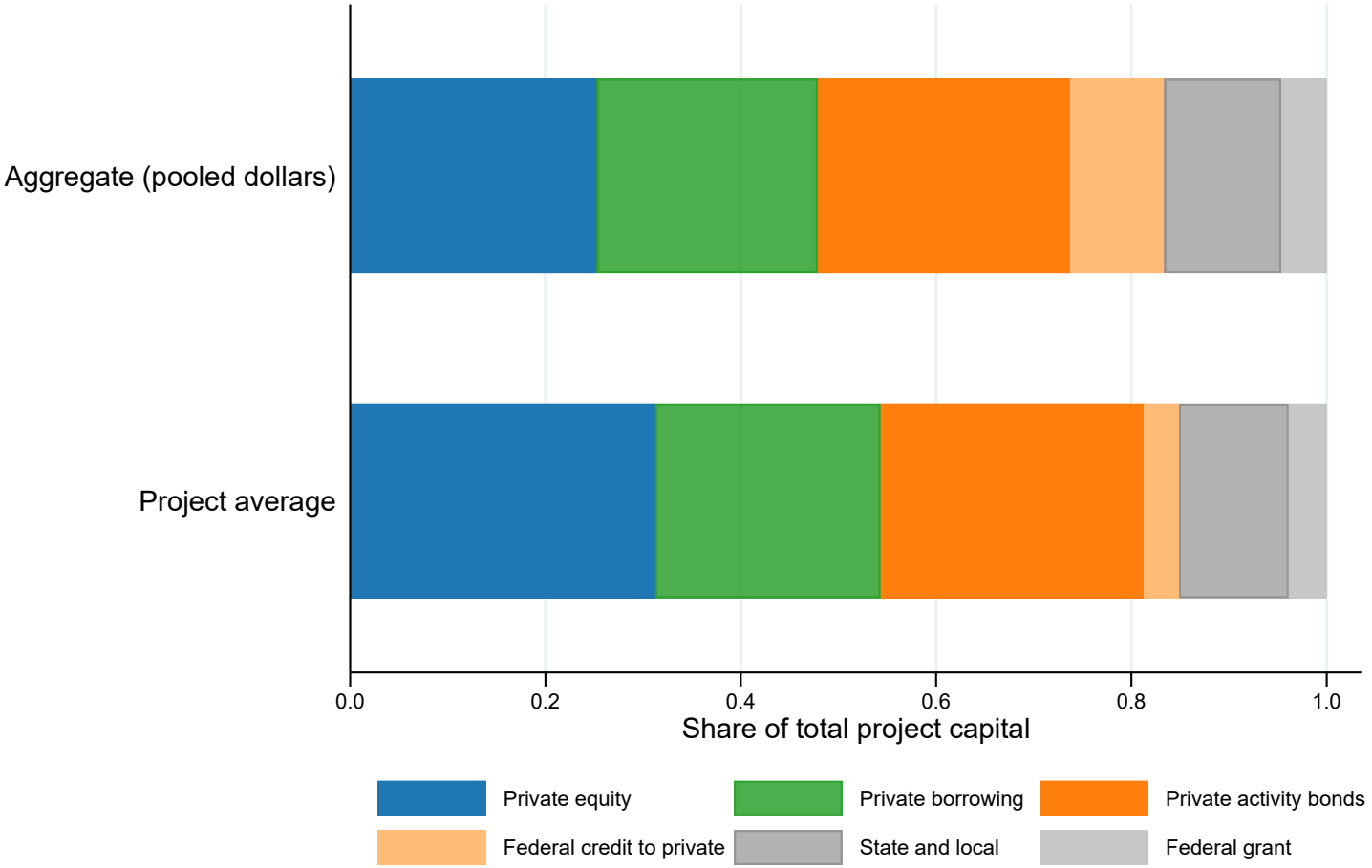
(b) Transport only

Figure 5: The financing mix of the private contribution



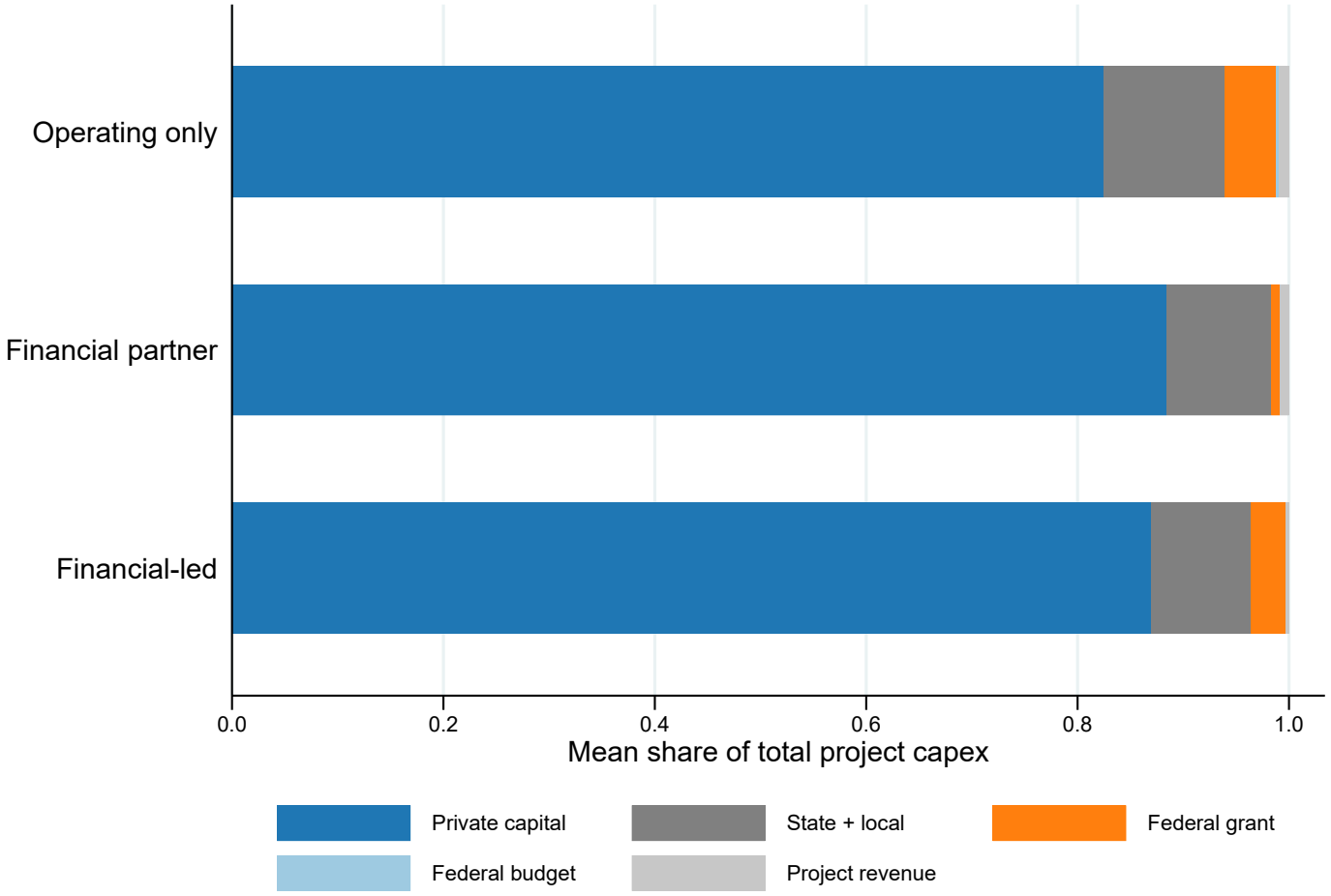
Note: Projects whose private stack is decomposed into instruments. Categories are mutually exclusive and exhaust the sample.
Source: Authors' compilation from FHWA, BAB, InfraPPP, Public Works Financing, WDBC handbooks, TxDOT and the US Major Transportation Projects Database.

Figure 6: The capital stack, aggregate and project-average



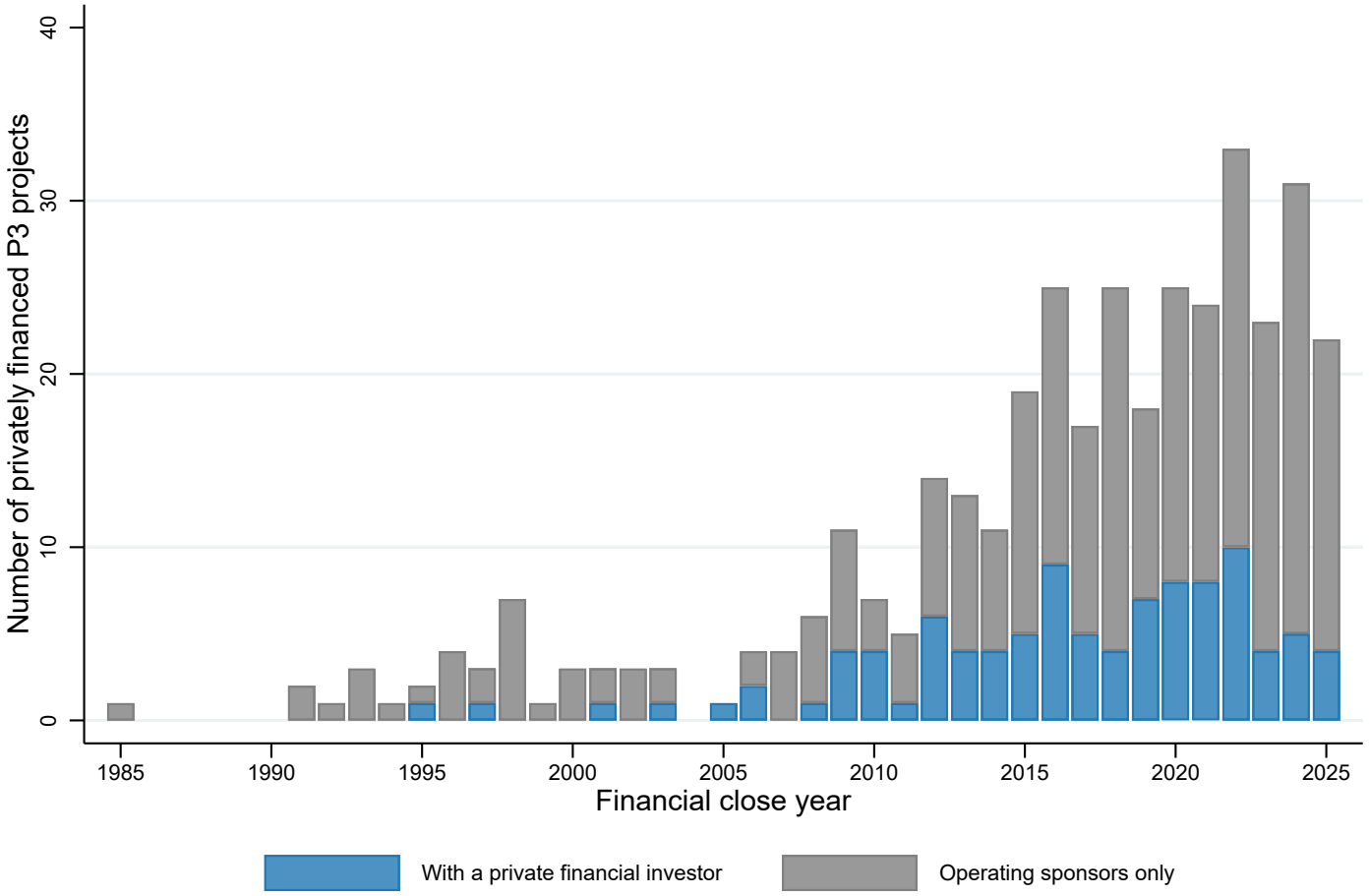
Note: Projects whose private stack is decomposed. The aggregate bar pools dollars across projects; the project-average bar is the mean of per-project shares.
Source: Authors' compilation from FHWA, BAB, InfraPPP, Public Works Financing, WDBC handbooks, TxDOT and the US Major Transportation Projects Database.

Figure 7: Capital stack by sponsor configuration



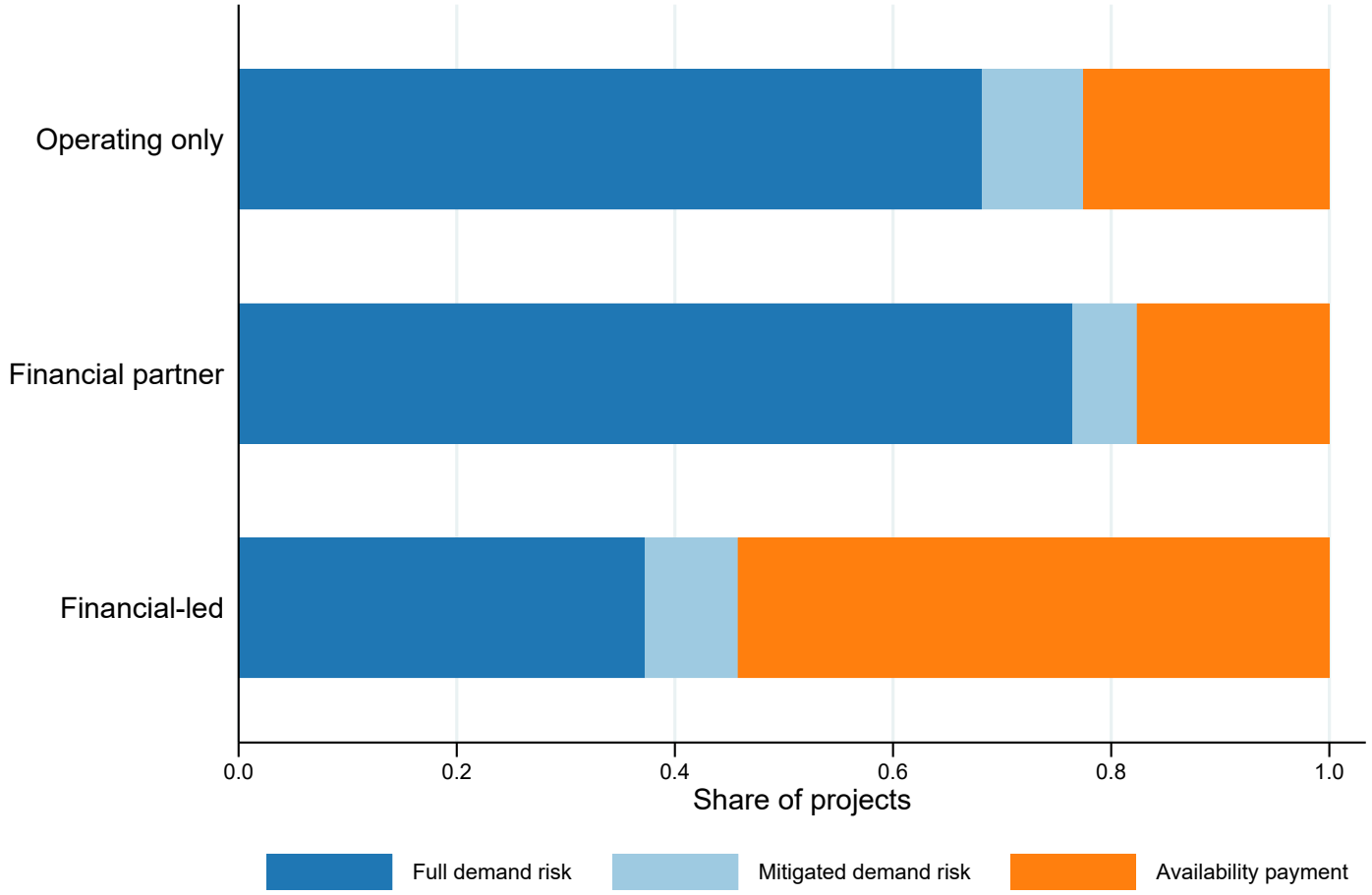
Note: Shares of total project capex; rows sum to one by construction.
Source: Authors' compilation from FHWA, BAB, InfraPPP, Public Works Financing, WDBC handbooks, TxDOT and the US Major Transportation Projects Database.

Figure 8: Privately financed P3 projects by financial close year



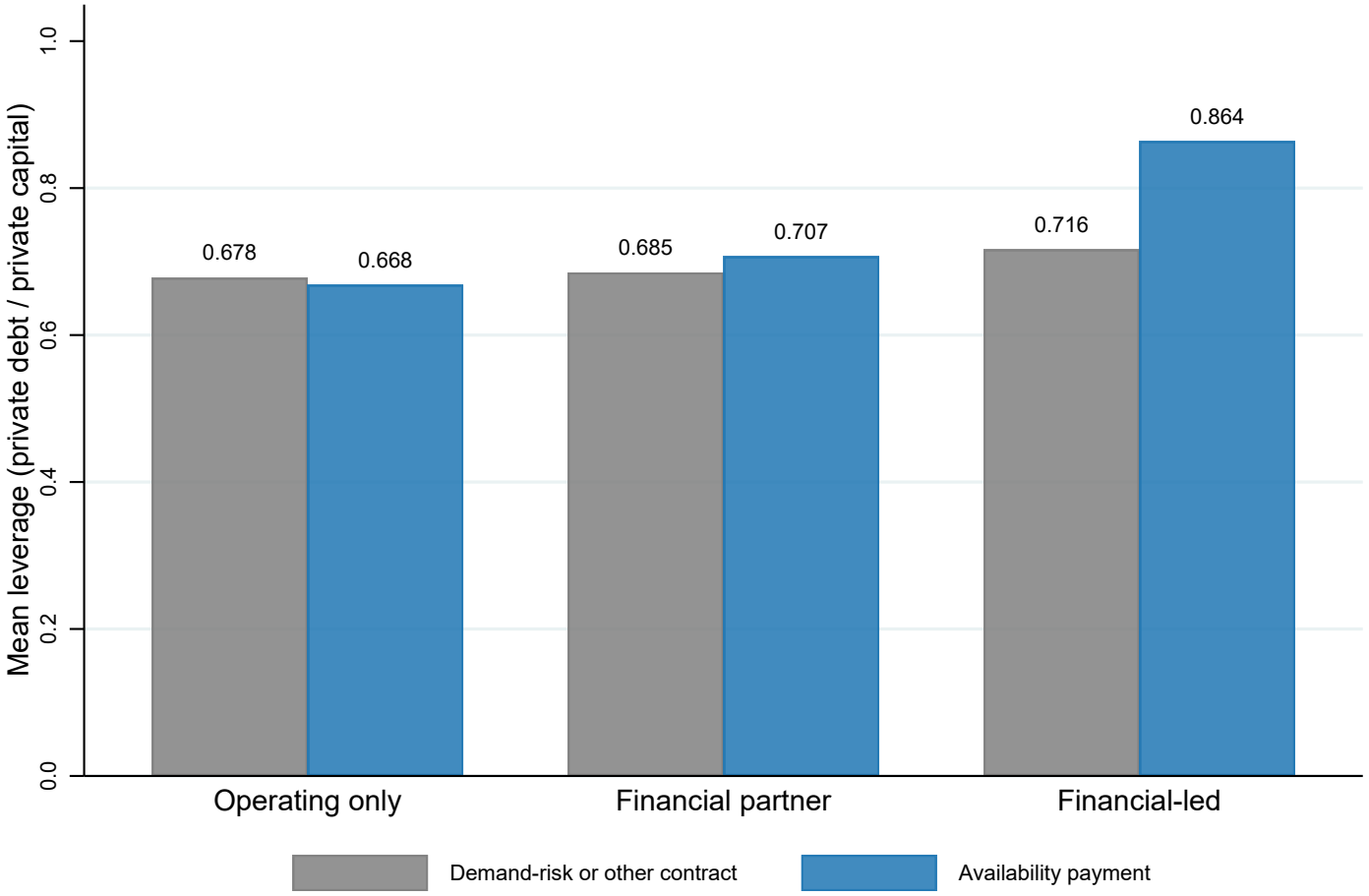
Note: Financial investors are classified from the firm's own investor type; a project counts as having one if any recorded sponsor is financial, which is a lower bound.
Source: Authors' compilation from FHWA, BAB, InfraPPP, Public Works Financing, WDBC handbooks, TxDOT and the US Major Transportation Projects Database.

Figure 9: Contracted allocation of demand risk by sponsor configuration



Note: Projects with a recorded concession term. Risk decreases from left to right:
under an availability payment the public sector bears demand risk.
Source: Authors' compilation from FHWA, BAB, InfraPPP, Public Works Financing, WDBC handbooks, TxDOT and the US Major Transportation Projects Database.

Figure 10: Leverage by sponsor configuration and contract form



Note: Project-finance architecture only, i.e. projects where both private equity and
private debt are observed and leverage is therefore a meaningful ratio. Winsorised 1/99.
Source: Authors' compilation from FHWA, BAB, InfraPPP, Public Works Financing, WDBC handbooks, TxDOT and the US Major Transportation Projects Database.

Table 1: The U.S. public-private partnership landscape

The table covers all 796 projects classified as P3 by delivery mode, not the analysis sample. Panel A reports the number of projects by sector and decade, the median total project cost, and the share of projects that are privately financed (a delivery mode that includes finance, or a lease-operate-maintain concession with an upfront fee). Panel B reports the same by delivery mode, together with the number that enters the analysis sample of Table 3 and the distribution of concession types. Concession shares are computed over projects with a recorded concession and sum to one within a row.

Panel A. P3 projects by sector and decade

	pre-2000	2000s	2010s	2020s	Not dated	All	Median capex, USD m	Private finance
Social Infrastructure	30	11	78	96	106	321	110	0.87
Transport	16	29	92	61	92	290	440	0.78
Utilities & Environment	14	38	48	56	29	185	43	0.59
All P3 projects	60	78	218	213	227	796	126	0.77

Panel B. Delivery modes

	Projects		Median	Private	Concession type		
	All	In sample	capex, USD m	finance	Full dem.	Mitigated	Availability
Design-build-finance-operate-maintain (DBFOM)	457	271	150	1.00	0.68	0.08	0.24
Design-build-operate-maintain (DBOM)	83	0	65	0.00	0.08	0.11	0.81
Lease-operate-maintain (LOM)	77	22	92	0.39	0.74	0.14	0.11
Design-build-finance (DBF)	46	39	133	1.00	0.38	0.00	0.63
Lease-expand-finance-operate-maintain (LEFOM)	37	31	150	1.00	0.74	0.15	0.11
Build-own-operate (BOO)	28	0	95	0.00	0.67	0.33	0.00
Design-build-finance-maintain (DBFM)	25	19	346	1.00	0.05	0.00	0.95
Design-build-finance-operate (DBFO)	20	10	100	1.00	0.70	0.10	0.20
Design-build-maintain (DBM)	17	0	640	0.00	0.10	0.10	0.80

Table 2: The capital stack of privately financed U.S. public-private partnerships

The table reports the share of total project capital expenditure contributed by each source at financial close, over the 368 projects of the analysis sample. The five sources exhaust the stack, so the shares sum to one within a project. Federal budget is direct federal agency funding of a federally owned asset; project revenue is capital funded from the project's own operating receipts.

	Mean	SD	Median	P25	P75	N
Private capital	0.839	0.253	1.000	0.736	1.000	392
State + local	0.109	0.201	0.000	0.000	0.135	392
Federal grant	0.042	0.140	0.000	0.000	0.000	392
Federal budget	0.002	0.021	0.000	0.000	0.000	392
Project revenue	0.008	0.055	0.000	0.000	0.000	392

Table 3: Construction of the analysis sample

The table traces the analysis sample from the full set of collected projects. A project enters the analysis sample if it is a P3 by delivery mode, it is privately financed (its mode includes private financing, or it is a lease-operate-maintain concession with an upfront fee), it reached financial close or began construction, and a private capital total is recorded. The two layers below differ in what a blank instrument field means: within Layer B a blank records that the instrument was not used, elsewhere that the split was never disclosed, so instrument-level variables are interpretable only within Layer B. Leverage is a continuous ratio only in the interior case; the remaining projects sit at corners with no project debt or no sponsor equity.

	Projects
Master sample, all infrastructure projects	1,815
P3 by delivery mode	796
of which privately financed (finance mode, or lease with upfront fee)	615
reached financial close or construction start, and private capital recorded	**392**
Layers of measurement	
Layer A: project totals observed	392
Layer B: private stack decomposed into instruments	309
of which equity and debt both observed (leverage defined)	156

Table 4: The two channels of federal support

The dependent variable is the private share of total capital expenditure in every column. Columns 1 and 2 estimate the price channel using an indicator for access to private activity bonds or federal credit. Columns 3 and 4 estimate the quantity channel using the federal grant share of capital expenditure. Columns 5 and 6 include both channels together. Columns 2, 4, and 6 add controls for availability-payment concessions and project revenue. Because the capital-stack shares sum to one, the grant coefficient reports where grant money lands in the stack rather than a behavioural crowd-out estimate. Standard errors clustered by state are in parentheses; * p<0.10, ** p<0.05, *** p<0.01.

	Price channel		Quantity channel		Both channels	
	Baseline	Adds contract controls	Baseline	Adds contract controls	Baseline	Adds contract controls
PAB or federal loan	0.056*	0.049			0.067**	0.062*
	(0.033)	(0.032)			(0.033)	(0.032)
Federal grant share of capex			-0.958***	-0.949***	-0.967***	-0.960***
			(0.066)	(0.068)	(0.065)	(0.066)
Availability payment		-0.033		-0.032		-0.029
		(0.032)		(0.033)		(0.031)
Project earns user fees		0.052		0.035		0.026
		(0.035)		(0.040)		(0.040)
Log total capex	-0.002	-0.001	-0.005	-0.004	-0.010	-0.008
	(0.010)	(0.010)	(0.006)	(0.006)	(0.006)	(0.006)
Subsector FE	x	x	x	x	x	x
Close-year FE	x	x	x	x	x	x
N	369	369	369	369	369	369
R-squared	0.192	0.200	0.381	0.386	0.394	0.397

Table 5: What a federal grant dollar displaces

The dependent variable is the private share of capital expenditure in column 1 and the state and local share in column 2. The independent variable of interest is the federal grant share of capital expenditure. Together the two columns say which component of the stack a grant displaces. Standard errors clustered by state are in parentheses; * p<0.10, ** p<0.05, *** p<0.01.

	Private share	State + local share
Federal grant share of capex	-0.958***	-0.078
	(0.066)	(0.054)
Log total capex	-0.005	0.004
	(0.006)	(0.006)
Observations	369	369
R-squared	0.381	0.155

Table 6: Project scale, contract form and capital structure by sponsor configuration

The table reports the mean, the median and the number of non-missing observations for each sponsor configuration over the analysis sample. Concession length including the extension adds the option to extend where one is recorded; only 40 of 273 concessions record an option and 34 of those are operating-only projects, so both measures are shown. The three concession indicators are computed over all projects rather than only those with a recorded concession, so they do not sum to one.

	Operating only			Financial partner			Financial-led		
	mean	p50	count	mean	p50	count	mean	p50	count
Total capex, USD m	478.42	116.50	288	1,585.69	460.40	37	1,046.07	400.00	65
Private capital, USD m	377.50	98.93	288	1,410.96	367.40	37	855.01	345.50	65
Concession length (years)	38.46	35.00	204	51.24	51.00	34	38.51	33.00	59
Concession length, incl. ext.	41.99	35.00	204	52.26	51.00	34	39.66	33.00	59
Full demand risk	0.48	0.00	288	0.70	1.00	37	0.34	0.00	65
Mitigated demand risk	0.07	0.00	288	0.05	0.00	37	0.08	0.00	65
Availability payment	0.16	0.00	288	0.16	0.00	37	0.49	0.00	65
Concession term recorded	0.71	1.00	288	0.92	1.00	37	0.91	1.00	65
Private share of capex	0.83	1.00	288	0.88	1.00	37	0.87	1.00	65
State + local share	0.12	0.00	288	0.10	0.00	37	0.09	0.00	65
Federal grant share	0.05	0.00	288	0.01	0.00	37	0.03	0.00	65

Table 7: Financial investors and the architecture of project financing

The dependent variable is an indicator for the financing structure named in the column heading: any project-level private debt in column 1, and project finance – sponsor equity and debt both present – in columns 2 and 3. The independent variables of interest are indicators for a financial partner and for a financial-led consortium; the omitted category is a project whose sponsors are operating firms only. Column 1 is estimated on the analysis sample, and columns 2 and 3 on the projects whose private stack is decomposed into instruments. Every column controls for log total project cost and absorbs sector and decade fixed effects. Column 3 repeats column 2 counting only debt that is unambiguously at the project level – private activity bonds, federal credit and project bonds – and excluding bank and other borrowing, which may sit on a sponsor's own balance sheet. Standard errors clustered by state are in parentheses; * p<0.10, ** p<0.05, *** p<0.01.

	Uses debt	Project fin.	Project fin. (project-level debt)
Financial-led	0.133**	0.226***	0.155**
	(0.051)	(0.060)	(0.059)
Financial partner	0.030	0.233**	0.069
	(0.090)	(0.102)	(0.071)
Log total capex	0.103***	0.122***	0.102***
	(0.017)	(0.016)	(0.019)
Subsector FE	Yes	Yes	Yes
Decade FE	Yes	Yes	Yes
Observations	387	304	304
R-squared	0.277	0.323	0.303

Table 8: **Financial sponsors divide a given contribution across more instruments**

The dependent variable is the number of distinct instruments in the private capital stack. The independent variables of interest are indicators for a financial partner and for a financial-led consortium; the omitted category is projects sponsored only by operating firms. The sample is projects whose private stack is decomposed into instruments. Column 1 controls for log total project cost, column 2 for log private capital, and column 3 for both. All columns absorb subsector and decade fixed effects. Holding private capital rather than total project size fixed matches the proposition, since the prediction concerns the composition of a given contribution rather than scale. Standard errors clustered by state are in parentheses. Statistical significance: * p<0.1, ** p<0.05, *** p<0.01.

	Total capex	Private capital	Both
Financial-led	0.303***	0.288***	0.290***
	(0.101)	(0.104)	(0.105)
Financial partner	0.493***	0.469***	0.471***
	(0.137)	(0.135)	(0.133)
Log private capital		0.154***	0.208***
		(0.029)	(0.060)
Log total capex	0.149***		-0.063
	(0.032)		(0.071)
Subsector FE	x	x	x
Decade FE	x	x	x
N	304	304	304
R-squared	0.348	0.364	0.365

Table 9: Financial control and the contracted allocation of demand risk

The dependent variables are, by column, an indicator for an availability-payment concession, an indicator for a full demand-risk concession, and an index of the demand risk borne privately taking the value three under a full demand-risk concession, two under a mitigated one and one under an availability payment. The independent variables of interest are indicators for a financial partner and for a financial-led consortium; the omitted category is a project whose sponsors are operating firms only. Every column controls for log total project cost and absorbs sector and decade fixed effects. All three columns are estimated on projects with a recorded concession, so that a zero means not this contract type rather than unknown. The p-row reports the test that the two financial coefficients are equal. Standard errors clustered by state are in parentheses; * p<0.10, ** p<0.05, *** p<0.01.

	Availability	Full demand	Revenue risk
Financial-led	0.230***	-0.228***	-0.459***
	(0.057)	(0.064)	(0.117)
Financial partner	-0.113	0.083	0.196
	(0.076)	(0.088)	(0.161)
Log total capex	0.006	-0.010	-0.016
	(0.022)	(0.021)	(0.042)
p(partner = led)	0.000	0.001	0.001
Subsector FE	Yes	Yes	Yes
Decade FE	Yes	Yes	Yes
Observations	295	295	295
R-squared	0.253	0.337	0.270

Table 10: Concession length is composition, not a negotiated term

The dependent variable is the concession length in years. The independent variables of interest are indicators for a financial partner and for a financial-led consortium; the omitted category is a project whose sponsors are operating firms only. Every column controls for log total project cost and absorbs subsector and decade fixed effects. Column 1 uses all contracts; column 2 availability-payment concessions only; column 3 demand-risk concessions only. Availability deals are shorter and financial-led sponsors sit in them, which is what produces the unconditional gap. The conditional cells are small, so columns 2 and 3 are low-powered nulls rather than demonstrated equalities. Standard errors clustered by state are in parentheses; * p<0.10, ** p<0.05, *** p<0.01.

	All contracts	Availability	Demand risk
Financial-led	-1.861	3.791	0.600
	(3.486)	(2.839)	(4.543)
Financial partner	11.626***	8.815***	8.504**
	(3.664)	(2.214)	(4.000)
Log total capex	2.365**	3.315***	1.737**
	(0.904)	(1.132)	(0.677)
Subsector FE	x	x	x
Decade FE	x	x	x
N	295	79	212
R-squared	0.244	0.498	0.353

Table 11: The availability result is not driven by delivery mode or sponsor count

The dependent variable is an indicator for an availability-payment concession in every column. The independent variables of interest are indicators for a financial partner and for a financial-led consortium; the omitted category is a project whose sponsors are operating firms only. The sample is projects with a recorded concession, so a zero means not this contract type rather than unknown. Every column controls for log total project cost and absorbs subsector and decade fixed effects. Column 2 adds bundling depth, measured as the number of lifecycle tasks named in the delivery mode excluding finance. Column 3 adds the number of private entities recorded. Column 4 adds both controls. Standard errors clustered by state are in parentheses; * p<0.10, ** p<0.05, *** p<0.01.

	Baseline	Bundling depth	Sponsor count	Both controls
Financial-led	0.230***	0.222***	0.220***	0.209***
	(0.057)	(0.058)	(0.056)	(0.057)
Financial partner	-0.113	-0.108	-0.144*	-0.144*
	(0.076)	(0.072)	(0.079)	(0.076)
Log total capex	0.006	0.009	0.003	0.005
	(0.022)	(0.022)	(0.020)	(0.020)
Lifecycle tasks bundled (excl. finance)		-0.044		-0.048
		(0.042)		(0.041)
Private entities recorded			0.030	0.034
			(0.035)	(0.034)
Subsector FE	x	x	x	x
Decade FE	x	x	x	x
N	295	295	295	295
R-squared	0.253	0.258	0.255	0.261

Table 12: **Sponsor configuration, contract form and leverage**

The dependent variable is leverage, private debt over private capital, in columns 1 through 5 and leverage defined using only debt unambiguously at the project level in column 6. The independent variables of interest are indicators for a financial partner and for a financial-led consortium; the omitted category is a project whose sponsors are operating firms only. Columns 1 through 5 use the project-finance sample, where both sponsor equity and project debt are observed. Column 2 adds an indicator for an availability-payment concession. Columns 3 and 4 replace the additive specification with an interaction between financial-led sponsorship and availability payment. Column 5 restricts the sample to availability-payment concessions within the project-finance sample. Column 6 repeats the baseline using the conservative debt definition, counting only private activity bonds, federal credit and project bonds as debt. Every column absorbs sector fixed effects; columns 1 through 3 also absorb decade fixed effects. Standard errors clustered by state are in parentheses. Statistical significance: * p<0.1, ** p<0.05, *** p<0.01.

	Project-finance sample				Availability-only sample	Project-level debt sample
	Baseline	Adds AP control	Interaction		Baseline	Conservative debt
Financial-led	0.109***	0.096**	0.043	0.043	0.194**	0.135**
	(0.037)	(0.041)	(0.051)	(0.046)	(0.080)	(0.063)
Financial-led × availability			0.137	0.142*		
			(0.087)	(0.079)		
Availability payment		0.046	-0.004	-0.001		
		(0.042)	(0.058)	(0.053)		
Financial partner	-0.004	-0.003	-0.000	0.013	0.031	0.063
	(0.043)	(0.042)	(0.042)	(0.043)	(0.112)	(0.045)
Log total capex	-0.018	-0.018	-0.016	-0.017	0.053*	-0.027
	(0.012)	(0.012)	(0.012)	(0.011)	(0.027)	(0.019)
Sector FE	x	x	x	x	x	x
Decade FE	x	x	x			
N	154	154	154	154	45	98
R-squared	0.110	0.119	0.137	0.104	0.272	0.077

Table 13: The composition of the private capital stack by sponsor configuration

The table reports the mean, the median and the number of non-missing observations for each sponsor configuration, over the projects whose private stack is decomposed into instruments. Leverage is private debt over private capital and the equity share is sponsor equity over private capital; both pool the three financing architectures here, and the sample in which leverage is a meaningful continuous ratio is the 176 projects reporting both sponsor equity and project debt, which is the sample used wherever leverage is an outcome. The three instrument indicators are computed over every project in the layer, which is why their counts exceed the counts on the ratios.

	Operating only			Financial partner			Financial-led		
	Mean	Median	N	Mean	Median	N	Mean	Median	N
Leverage	0.818	0.923	153	0.712	0.725	28	0.820	0.896	52
Equity share	0.607	0.627	148	0.355	0.279	29	0.327	0.209	52
Bond share	0.801	0.975	96	0.475	0.466	15	0.711	0.862	35
Subsidised debt share	0.788	0.937	96	0.641	0.636	15	0.729	0.850	27
Uses PABs	0.398	0.000	216	0.419	0.000	31	0.417	0.000	60
Federal loan to private party	0.065	0.000	216	0.323	0.000	31	0.117	0.000	60
PAB or federal loan	0.444	0.000	216	0.484	0.000	31	0.450	0.000	60

Table 14: Where the leverage gap is

The dependent variable is leverage, private debt over private capital, in every column. The independent variables of interest are indicators for a financial partner and for a financial-led consortium; the omitted category is a project whose sponsors are operating firms only. The sample is projects in the project-finance architecture, where both sponsor equity and project debt are observed. Columns 1 and 2 restrict to availability-payment concessions; column 2 adds bundling depth, measured as the number of lifecycle tasks named in the delivery mode excluding finance. Column 3 restricts to demand-risk concessions. Every column controls for log total project cost and absorbs sector fixed effects. Standard errors clustered by state are in parentheses; * p<0.10, ** p<0.05, *** p<0.01.

	Availability-payment sample		Demand-risk sample
	Baseline	Adds bundling depth	Baseline
Financial-led	0.194**	0.196**	0.050
	(0.080)	(0.077)	(0.045)
Financial partner	0.031	0.034	0.030
	(0.112)	(0.111)	(0.043)
Log total capex	0.053*	0.053*	-0.032**
	(0.027)	(0.027)	(0.013)
Lifecycle tasks bundled (excl. finance)		-0.013	
		(0.068)	
Sector FE	x	x	x
N	45	45	109
R-squared	0.272	0.274	0.060

Table 15: Financial sponsors obtain no larger subsidized-debt share

The dependent variable is the subsidized share of private capital in every column, defined as private activity bonds plus federal credit lent to the private party, divided by private capital. The independent variables of interest are indicators for a financial partner and for a financial-led consortium; the omitted category is a project whose sponsors are operating firms only. The sample is projects where the private stack is decomposed, so the subsidy measure is observed rather than missing by construction. Every column controls for log total project cost and absorbs decade fixed effects. Columns 1 and 3 absorb sector fixed effects; columns 2 and 4 replace those with the finer subsector partition. Column 3 adds bundling depth, measured as the number of lifecycle tasks named in the delivery mode excluding finance. Column 4 also adds the number of private entities recorded. Standard errors clustered by state are in parentheses; * p<0.10, ** p<0.05, *** p<0.01.

	Baseline	Subsector FE	Adds bundling depth	Adds both controls
Financial-led	0.171**	0.143	0.171**	0.144
	(0.078)	(0.088)	(0.078)	(0.088)
Financial partner	0.033	0.022	0.035	0.031
	(0.073)	(0.079)	(0.072)	(0.092)
Lifecycle tasks bundled (excl. finance)			-0.014	-0.020
			(0.061)	(0.060)
count of private entities recorded for the project				-0.008
				(0.035)
Log total capex	-0.031	-0.036	-0.030	-0.033
	(0.023)	(0.022)	(0.023)	(0.021)
Sector FE	x		x	
Subsector FE		x		x
Decade FE	x	x	x	x
N	81	78	81	78
R-squared	0.222	0.292	0.224	0.296

Table 16: Projects where federal credit is lent to the private party

The table reports the mean, the median and the count for the 30 projects in the decomposed layer where TIFIA or WIFIA lends to the private party: 13 whose sponsors are operating firms only and 17 with a financial investor, the latter pooling ten financial-partner and seven financial-led projects. Federal loans to public borrowers are recorded separately and show no such tilt. Thirty events cannot support a sponsor-level inference, so no test is reported. Use of tax-exempt private activity bonds is nearly identical across the two groups, 45.6 against 40.4 percent, so the difference is specific to who borrows rather than to who is subsidised.

	Operating only			Financial investor		
	Mean	Median	N	Mean	Median	N
Total capex, USD m	685.46	613.75	14	3,152.01	1,664.30	17
Private capital, USD m	598.66	547.00	14	2,746.11	1,292.30	17
Federal credit to private, USD m	242.01	199.65	14	906.66	473.70	17
Private share of capex	0.77	0.88	14	0.78	0.78	17
Full demand risk	0.50	0.50	14	0.65	1.00	17
Availability payment	0.14	0.00	14	0.35	0.00	17
Leverage	0.74	0.78	14	0.74	0.79	17
Subsidised debt share	0.60	0.66	14	0.62	0.62	17

Appendix

A1 Variable Definitions

Panel A lists the collected fields used in the paper and Panel B the variables constructed from them. Monetary amounts are millions of U.S. dollars as reported at financial close, unconverted and not deflated. A blank on the public side of the stack is read as zero; a blank on the private side is read as undisclosed, which is the distinction that defines the two measurement layers in Section 4.3. Continuous variables are winsorised at the 1st and 99th percentiles wherever they enter a mean or a regression.

Table A1: Variable definitions

Variable	Definition
Panel A. Collected fields	
State, sector, subsector, industry	Location and the three levels of the project taxonomy in Appendix A4.
Delivery mode	Contractual delivery structure: DBFOM, DBF, DBFM, DBFO, DBOM, DBM, lease-operate-maintain, LEFOM, build-own-operate, design-build, design-bid-build, or other.
Private entity	The private firms named in the project documents, parsed into individual sponsors with their equity shares where stated.
Concession years, by type	Length in years, recorded separately for full demand-risk, mitigated demand-risk and availability-payment concessions, so the contract type is identified by which field is populated.
Option extension years	Additional years available through a contractual extension option.
Primary revenue type	Toll, fare, rent, fee, or free (no user charge).
Financial close date, construction start	Date of financial close; where unavailable, imputed as construction start minus two months.
P3 capex at financial close	Capital expenditure as recorded in the financial close documentation.
`fed_grant_to_state`, `fed_grant_to_local`	Federal grant funding channelled through a state or a local agency.
`state_fed_loan`, `local_fed_loan`	Federal loans to a state or local *public* borrower, recorded separately from federal credit lent to the private party.
`state_cash_contrib`, `local_cash_contrib`	Upfront cash from state or local agencies, including dedicated taxes and levies.
`state_muni_bond`, `local_muni_bond`	Municipal bonds issued by a state-level or local government entity.
`state_other_loan`, `local_other_loan`	Loans to a state or local agency from a non-federal source.
`fed_bgt`	Direct federal budget allocation to a federally owned asset.
`fund_from_proj_rev`	Capital funded from the project's own operating receipts, including philanthropic gifts.
`pvt_equity`	Equity contributed by the private sponsor or consortium.
`pvt_act_bond`	Tax-exempt private activity bonds issued by a public conduit on behalf of the private party.

Continued on next page

Table A1 continued

Variable	Definition
pvt_taxable_bond	Taxable bonds issued by the private party.
pvt_bank_loan	Commercial bank borrowing by the private party.
pvt_other_bwr	Borrowing from infrastructure debt funds, private placements, commercial paper and other non-bank lenders.
fed_loan_to_pvt	Federal credit (TIFIA or WIFIA) lent to the private party.
value_ref_source, ref_url1–ref_url19	Verbatim quotation from the source document supporting the financing values, and the URLs of the documents they came from.
Panel B. Constructed variables	
ttl_capex, ln_capex	Total project cost: the sum of the public sources and private capital, falling back to the recorded capex at financial close; and its log.
pvt_ttl_capex_adj	Private capital: the recorded private total plus any unexplained residual capex.
gov_capex, fed_grant	State plus local capital; federal grants plus federal budget.
pvt_share, gov_share, fed_share	Private capital, state and local capital, and federal grant money, each over total capex.
pvt_debt	PABs + taxable bonds + bank loans + other borrowing + federal credit to the private party.
pvt_debt_projlvl	PABs + federal credit + taxable project bonds: private debt unambiguously at the project level, excluding bank and other borrowing, which may be sponsor corporate debt.
subsid_debt	pvt_act_bond + fed_loan_to_pvt: federally subsidised private debt.
leverage, leverage_projlvl	Private debt over private capital, on all private debt and on project-level debt only.
equity_share	pvt_equity over private capital.
subsid_share, pvt_bond_share	Federally subsidised private debt, and bond financing, each over private capital.
n_pvt_instr	Number of distinct private instruments recorded.
has_pab, has_tifia	One if the project uses private activity bonds; one if federal credit is lent to the *private* party. Federal loans to public borrowers are not counted in has_tifia.
has_subsid_debt, uses_pvt_debt	One if the project uses PABs or federal credit; one if any project-level private debt is recorded.
conc_type	0 none, 1 full demand risk, 2 mitigated demand risk, 3 availability payment. Classification rules in Appendix A3.
conc_risk	Demand risk borne privately: 3 full demand, 2 mitigated, 1 availability.
conc_full_dem, conc_mitig, conc_avail, has_conc	Indicators for each concession type, and for a concession type being recorded at all.
conc_yr_all, conc_yr_ext	Concession length in years, whichever type applies; and that length plus the extension option. Only 40 of 273 concessions record an extension and 34 of those are operating-only projects, so both are reported.
has_proj_rev	One unless the primary revenue type is free: the project earns user fees.
bundle_depth	Number of lifecycle tasks named in the delivery mode, *excluding* finance.

Continued on next page

Table A1 continued

Variable	Definition
n_sponsors	Private entities recorded for the project.
sponsor_class	Operating only / financial partner (present but not lead) / financial-led. The lead is the largest recorded equity holder, else the first-listed entity; a firm is financial if its own investor type or industry is financial, not because of its role in the deal.
fin_architecture	Corporate balance sheet / conduit bond (no sponsor equity) / project finance (equity and debt) / undisclosed.
split_known	One if the private total is known and at least one private instrument is recorded.
stack_decomposed	One if *both* private equity and private debt are observed: the only sample in which leverage is a meaningful continuous ratio.
deal_yr, decade	Financial close year, else construction start year; and that year bucketed pre-2000 / 2000s / 2010s / 2020s.
analysis_sample	P3 by delivery mode, mode includes finance, reached financial close or construction start, private capital recorded. Lease monetisations with no construction capex and projects whose cost is an "amount undisclosed" placeholder are excluded.
layer_a_sample, layer_b_sample	The analysis sample; and the analysis sample restricted to projects whose private stack is decomposed. Instrument-level variables are interpretable only in the second.

A2 Sample Construction and Data Collection

This appendix describes the sources, the procedure used to build the unified project-level dataset, and the collection of the financing and sponsor variables.

Part I. Sources

Seven sources are merged in descending order of definitiveness, so that the most reliable identifiers anchor the sample before less standardized sources are matched to it.

1. **Federal Highway Administration (FHWA).** A public inventory of surface transportation P3s with project descriptions, delivery modes, financial close status and timeline.[2] It is the most authoritative source for its sector, gives limited financing detail, and covers no other sector.

2. **Build America Bureau (BAB).** Administers TIFIA loans and PAB allocations, and records loan amounts, issuance volumes and project detail for projects receiving federal credit assistance.[3]

3. **InfraPPP.** A P3-oriented database tracking projects globally, including concession terms and partial financing detail.[4] It provides the broadest sector coverage of the sources, extending the sample to water, energy and social infrastructure. Its U.S. coverage is comparable in scope to commercial platforms such as IJ Global and Infralogic, which mitigates the concern that a specialized database systematically underrepresents the P3 universe.

4. **Public Works Financing (PWF).** A trade publication tracking infrastructure project financing since the early 1990s.[5] It carries the most detailed capital structure information of the four original sources and fills in financing variables for projects already present from the others.

[2]FHWA Project Profiles: https://www.fhwa.dot.gov/ipd/project_profiles/.
[3]BAB financed projects: https://www.transportation.gov/buildamerica/projects/financing-search.
[4]InfraPPP: https://www.infrapppworld.com/.
[5]Public Works Financing: https://pwfinancing.com/.

5. **Water Design-Build Council (WDBC) handbooks, 3rd–6th editions.** Project rosters for the water and wastewater segment, which the transport-oriented sources underrepresent.[6]

6. **US Major Transportation Projects Database.** A research database of large U.S. transportation projects, with delivery method, cost and schedule histories and post-completion outcomes.[7] It is used here both to extend coverage of large transport projects and to cross-check the dates and costs of projects already in the sample; it is also the source for the ex-post outcome data on road projects noted in the conclusion.

7. **Texas DOT alternative delivery project list.** A state inventory for the jurisdiction with the largest and longest-running P3 program.[8]

Commercial databases (IJ Global, Infralogic, SDC Platinum) report aggregate deal values but do not decompose the capital stack into its funding sources. That decomposition is hand-collected here, as described in Part III.

Figure A1 maps the resulting coverage. The sample contains projects in all fifty states, the District of Columbia, Puerto Rico and the U.S. Virgin Islands, together with a small number of multi-state and federal projects.

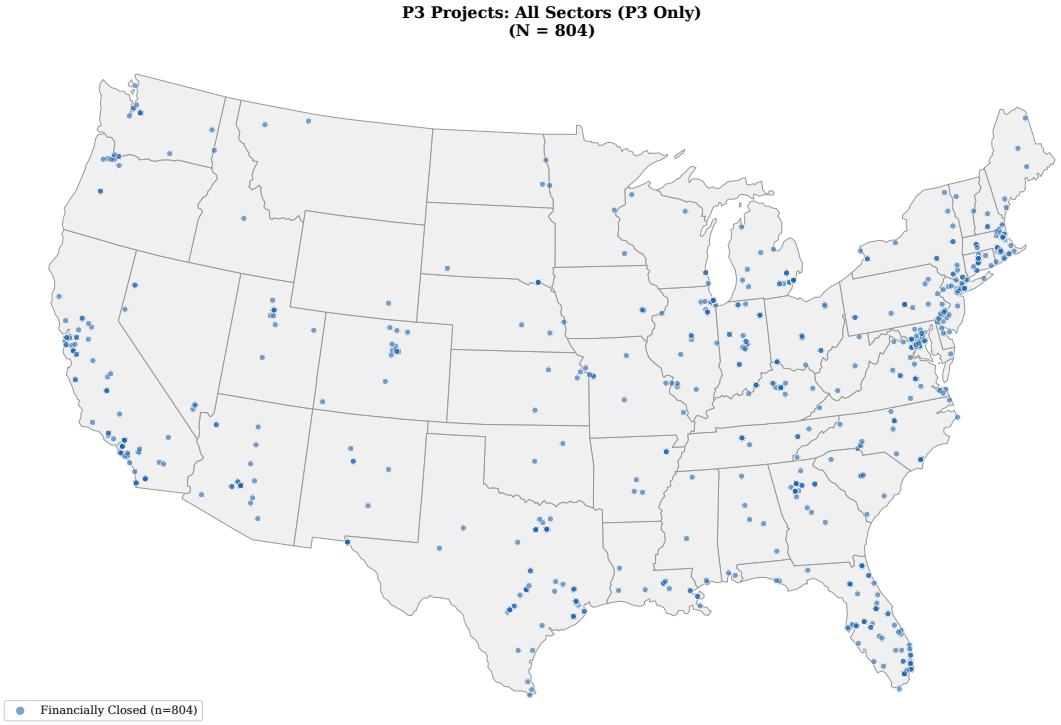
Part II. Project identification and deduplication

The absence of standardized project identifiers makes deduplication the central construction problem. The same project appears under different names ("I-595 Express" against "I-595 Corridor Roadway Improvements"), different geographic descriptions, and different attribute formats. A purely manual approach is infeasible at this scale and a purely automated one misses distinctions that matter, so the procedure is hybrid.

Step 1: base sample. The FHWA list (326 projects) is supplemented with BAB records (28 unique after deduplication), giving a base of 354 surface transportation projects.

[6] Water Collaborative Delivery Association handbooks: https://watercollaborativedelivery.org/handbook/.
[7] https://transportationprojects.org/.
[8] TxDOT alternative delivery: https://www.txdot.gov/business/road-bridge-maintenance/alternative-delivery.html#executed.

Figure A1: Geographic coverage of the P3 sample



Step 2: InfraPPP integration. InfraPPP's 924 U.S. entries are screened against the base sample by a large language model on name similarity, geography, sector and size; candidate matches are verified by a second model with richer attributes (delivery mode, contract value, sponsoring agency); remaining ambiguous cases are resolved by manual review of project documents. After deduplication InfraPPP contributes mainly non-transport projects.

Step 3: PWF, WDBC, TxDOT and UMD integration. The same matching procedure is applied to each subsequent source. PWF also contributes capital structure detail for projects already in the sample. Two project-name conflicts surfaced by the UMD match are resolved in code rather than by editing the input files, and one duplicate project identified during the merge is removed at ingest.

Step 4: standardization. Delivery-mode labels reported under different conventions are harmonized to a common taxonomy, and sector and industry codes are assigned from a hierarchical taxonomy developed for this study and verified project by project.

Part III. Financing data collection

Step 5: variable specification. Each project carries over forty variables covering contract terms, timeline, cost, and the capital stack decomposed into eleven components (Section 4.2).

Step 6: document search. Financing values are taken from primary sources, in the order in which they supply them in practice: sponsoring-agency disclosures and financial close summaries; sponsor and consortium press releases; trade publications and general press coverage; federal funding announcements; and, for the projects that issued them, bond official statements filed on EMMA. Value for Money analyses and board minutes are used where a project produced them, which is a minority of cases. Where two sources disagree, the one closer to financial close and more specific about the instrument is preferred. All of these report financing as of financial close, which is the relevant snapshot for capital structure.

Step 7: verification and traceability. Every extracted value is verified against its source document. Where sources disagree, the value with greater numerical precision and the value closest to financial close are preferred. Each figure is stored with a verbatim quotation from the source (`value_ref_source`) and up to nineteen source URLs (`ref_url1`–`ref_url19`), so that every number in this paper can be traced to the document it came from. Commercial databases report aggregate values without this documentation.

Step 8: the four passes. Collection runs in four passes, and the division of labour between them is deliberate.

1. *Model-assisted search.* A large language model with web access (Gemini 2.5 Flash) searches the public record for each project and returns candidate figures with their sources. This pass is fast and wide, and its output is treated as a set of leads rather than as data.

2. *Manual search and verification.* Each project is then worked by hand: the primary documents are located and read, the figures are taken from them directly, and each is recorded with the quotation that supports it. Nothing enters the dataset that has not been read in its source.

3. *Independent model check.* A second model (Claude Opus 5) is given the recorded values and asked to verify them against the documents independently, and to search further where the recorded stack does not reconcile. Because it works against the recorded values rather than from scratch, it flags disagreements rather than proposing figures.

4. *Manual adjudication.* Every discrepancy the third pass raises is reviewed by hand and resolved against the primary source. This is where the reclassifications in Part IV originate: a figure recorded as private capital that the documents show to be county revenue bonds or a conduit issue is caught here, not in the first pass.

The order matters. The search steps are model-assisted because reading the public record at this scale is otherwise infeasible; the recording and adjudication steps are manual because judging the authority of a source, and declining to commit a number when the sources do not support one, is the substance of the work rather than a formatting task. Passes three and four were run after the first draft of this paper and are the reason the decomposed layer grew from roughly half of the financially closed projects to 309 of 392.

Part IV. Post-2026 collection: sponsors, instruments, contracts

Three further collection stages were completed after the first draft of this paper. Table A2 summarizes them.

Sponsor standardization and typing. The raw sources record private participants as free text—one firm, a joint-venture name, or a semicolon- or comma-separated consortium—with heavy variant-form noise. A percentage-aware parser splits these strings into individual firms while preserving equity shares where stated, handling corporate suffixes and parenthetical abbreviations so that names are not split on internal commas. Projects are then routed to one of four research worksheets by ownership structure: joint ventures and special purpose LLCs, whose member composition must come from external sources; multi-partner consortia; single-entity projects; and projects with no recorded entity. Each worksheet is researched, reviewed manually, and finalized. Firms are then matched to Pitchbook company and investor

records and typed as financial or operating on the firm's own investor type and industry, not on its role in the individual deal. The typing rule and the boundary cases are in Section 4.4.

Private capital decomposition. Among financially closed projects with private capital, roughly half initially recorded the entire private contribution as a residual equity figure—the difference between project cost and the identified public sources. That residual is not a measurement of equity; it is a placeholder for private money of unknown structure, and treating it as equity would understate borrowing throughout. A second-round search was run over these projects, reading official financial-close documents, bond official statements and federal credit profiles to decompose the private total into instruments. The search covered 446 project records and resolved every one. It is not scriptable: judging source authority and refusing to commit a number when the sources do not support one is the substance of the work, so the search was conducted by an agent reading the documents and a script was used only to write verified findings into the file.

Reclassification and the concession audit. The same pass produced two by-products that change the sample rather than merely filling it in. Fifty-four projects were flagged for reclassification, most commonly because a figure recorded as private capital was public money—county revenue bonds, state authority issuance, or a general obligation bond behind what the source described as a private financing—or because conduit tax-exempt bonds had been recorded as at-risk equity. Separately, each project's concession classification was audited against the rules in Appendix A3, which relocated projects whose contractual form did not match their recorded type: publicly owned stormwater utilities billed to ratepayers, per-diem correctional contracts, and energy savings performance contracts are the recurring cases. Both sets of corrections are logged with their evidence and applied in code at the build step, each asserting the value it expects to replace, so that a change in an upstream source fails loudly rather than overwriting silently.

Table A2: Collection stages after the first draft

Stage	What it collects	What it changed
Sponsor standardization	Private entities parsed from free text, name variants resolved, equity shares preserved	Makes the sponsor unit of analysis possible
Firm typing	Each firm matched to Pitchbook and typed financial or operating on its own business	Defines the three sponsor configurations
Capital stack search	Second-round document search decomposing the private total into instruments, 446 records	Raises the decomposed layer to 309 projects
Reclassification	54 projects where recorded private capital proves to be public money or conduit debt	Corrects the private share and the architecture
Concession audit	Every concession type checked against the classification rules	Corrects the risk-allocation variable
UMD merge	Large transport projects, schedules and cost histories	Extends coverage and cross-checks dates

Each stage produces a reviewed file; a single build step assembles them into the analysis master, applying every logged correction in code. No input file is hand-edited.

A3 Concession Types

I classify each concession by its revenue mechanism into one of three types, which form a ladder of declining demand (volume) risk to the private partner. The organizing question is not the sector but *who bears the volume risk, and from whom the private partner is paid.*

Full demand-risk (user-fee) concessions (`full_dem_risk_conc_yr`). The private partner is paid directly by dispersed end users, so its revenue rises and falls with usage and it bears the full volume risk of the asset. Toll roads, parking facilities, and merchant projects are the canonical cases.

Mitigated demand-risk concessions (`mitig_dem_risk_conc_yr`). The private partner still earns revenue by selling a metered output it produces—treated or desalinated water, wastewater treatment, or power under a purchase agreement—but the volume risk is structurally muted. A monopoly franchise, inelastic demand for an essential good, and a contractual floor (a take-or-pay minimum or a rate covenant) insulate revenue from short-run fluctuations. These concessions sit between full demand risk and none; in the sample they are almost entirely water, wastewater, and contracted-power supply concessions in which the private partner *owns the asset and sells its output.*

Availability-payment concessions (`avail_pymt_yr`). The private partner bears no demand risk: it is paid a fixed charge for keeping the asset available and meeting performance standards, independent of how much the asset is used. This type covers the classic availability-payment infrastructure—roads, rail, and social buildings for which a public grantor pays

a unitary charge—together with operations-and- maintenance service contracts (including campus-utility and water/wastewater O&M deals) in which the public entity owns the system, retains any user revenue, and pays the private partner a fee to run it.

A water project can fall on *any* of the three rungs. What places it is whether the private partner *sells the output and absorbs the volume risk* (mitigated demand risk) or is merely *paid a fee to operate a publicly owned system that bills ratepayers* (availability). The raw indicator for whether the system charges a user fee cannot make this distinction on its own, because it records that the *system* bills users, not that the *private partner* bears the resulting demand risk.

Table A3: **Concession Types in the P3 Sample**

Concession type	Demand risk to private partner	Revenue mechanism	Representative examples
Full demand-risk (user-fee) `full_dem_risk_conc_yr`	Full	Paid directly by end users; revenue moves one-for-one with usage.	Toll roads, parking, merchant projects.
Mitigated demand-risk `mitig_dem_risk_conc_yr`	Low / mitigated	Sells a metered output it owns and produces, but volume risk is muted by monopoly franchise, inelastic demand, and a contractual floor (take-or-pay minimum or rate covenant).	Water and wastewater treatment, desalination, and bulk-supply concessions; contracted power (PPA).
Availability payment `avail_pymt_yr`	None	Paid a fixed charge for keeping the asset available and meeting performance standards, independent of use; also covers O&M service contracts where the public owner retains user revenue.	Roads, rail, and social-building availability schemes; campus-utility and water/wastewater O&M contracts.

Notes: Each concession is assigned to exactly one type. The types form a ladder of declining demand (volume) risk borne by the private partner. The decisive criterion is who bears the volume risk—the private partner fully (full demand-risk), the private partner but cushioned by monopoly and a contractual floor (mitigated demand-risk), or not the private partner at all (availability payment)—rather than the project's sector. A water or wastewater project can therefore appear on any rung: it is a mitigated demand-risk concession when the private partner owns the asset and sells its output, and an availability-payment (O&M service) arrangement when the public entity owns the system, bills ratepayers, and pays the private partner a fixed fee to operate it.

A4 Sector Taxonomy

Projects are classified with a hierarchical taxonomy of three top-level sectors, fourteen subsectors and sixty detailed industry codes, developed for this study and assigned project by project. The taxonomy keys on the economic function of the asset rather than its physical form, so that a parking garage on a university campus and a municipal parking garage sit in different subsectors while a university central utility plant and a municipal water plant sit in different ones again. Sector fixed effects in the paper are defined at the sector level and the finer industry fixed effects at the code level.

- **Transport** (22 codes): Road, Rail & Transit Network, Air, Sea & River, and Transit Facility.
- **Social Infrastructure** (24 codes): Healthcare, Justice & Public Safety, Government Admin, Community & Public Space, and Education.
- **Utilities & Environment** (14 codes): Digital, Water & Waste, Energy, and Environment.

One project carries a legacy variant of the Community & Public Space subsector label and appears as a separate row in Figure 2; it is a labelling artefact rather than a fifteenth subsector.

Table A4: Sector and industry taxonomy

Sector	Sub-sector	Code	Description
Panel A: Transport (22 codes)			
Transport	Air	`air_bldg`	Passenger terminals, cargo facilities, hangars, and landside infrastructure.
		`air_rail`	Intra-airport rail infrastructure and Automated People Movers (APMs).
		`air_mgmt`	Operations-only concessions and facility management for existing airport assets.
	Sea & River	`port_bldg`	Development of physical maritime infrastructure.

Continued on next page

Table A4 continued

Sector	Sub-sector	Code	Description
		port_mgmt	Operations-only concessions and terminal operating services.
	Road	road_smart	Connected/Autonomous Vehicle lanes, smart corridors, and IoT sensor networks.
		road_bridge	Standalone major bridges and viaducts.
		road_tunnel	Major roadway tunnels.
		road_facility	Highway rest areas, service plazas, weigh stations, and maintenance depots.
		road_highway	Controlled-access freeways and Interstates.
		road_arterial	Strategic urban corridors and major surface highways.
		road_local	Rural roads, local streets, and bundled small bridge programs.
	Rail & Transit Network	rail_high_speed	High-performance lines with speeds >125 mph.
		rail_heavy_metro	Rapid transit, subways, and light metro systems.
		rail_light	Light Rail Transit, streetcars, trams, and cable cars.
		trans_brt_line	Bus Rapid Transit with dedicated lanes.
		trans_logistics	Intermodal transfer facilities and freight distribution centers.
		rail_freight	Industrial/cargo rail tracks and signaling.
		rail_intercity	Conventional long-distance passenger rail.
		rail_commuter	Conventional heavy rail connecting suburbs to CBDs.
	Transit Facility	trans_rail_center	Multi-modal transit hubs and transit-oriented development.
		trans_bus_center	Bus terminals, intercity coach stations, and park-and-ride.
Panel B: Social (24 codes)			
Social	Healthcare	health_hospital	Acute care hospitals and medical centers.
		health_care	Outpatient clinics, elderly care, and mental health facilities.
	Justice & Public Safety	justice_court	Federal, state, and municipal courthouses.
		corr_prison	Prisons, detention centers, and jails.
		safety_emerg_bldg	Police headquarters, fire stations, and emergency centers.
	Government Admin	admin_office	Government workplaces and administrative offices.
		military_housing	Military residential assets on federal bases.

Continued on next page

Table A4 continued

Sector	Sub-sector	Code	Description
		`military_bldg`	Vertical construction on military bases (non-housing).
		`military_other`	Base infrastructure: training ranges and maintenance depots.
	Community & Public Space	`housing_res`	Affordable and social housing developments.
		`civic_cultural`	Convention centers, museums, performing arts centers, and libraries.
		`rec_leisure`	Public parks, sports complexes, and recreational space.
		`mx_use`	Multi-use projects blending commercial space with housing.
		`muni_parking_infra`	Construction of new municipal parking garages.
		`muni_parking_mgmt`	O&M-only management of existing parking inventories.
		`urban_renewal`	District-level regeneration programs.
	Education	`edu_energy`	Central utility plants and microgrids for universities.
		`edu_energy_mgmt`	Energy efficiency/retrofits for existing university systems.
		`edu_lab`	Academic research buildings and laboratories.
		`edu_instruction`	Instructional facilities and campus expansions.
		`edu_housing`	Student dormitories and faculty housing.
		`edu_rec`	Campus stadiums, arenas, and recreation centers.
		`edu_parking_infra`	Construction of new campus parking garages.
		`edu_parking_mgmt`	O&M-only concession of existing campus parking.
Panel C: Utilities & Environment (14 codes)			
Utilities & Env.	Digital	`util_telecom`	Broadband infrastructure, fiber optic networks, and cellular towers.
	Water & Waste	`util_water`	Drinking water treatment, desalination, and distribution.
		`util_wastewater`	Sewerage systems and wastewater treatment plants.
		`solid_waste`	Landfills, transfer stations, and waste-to-energy plants.
		`util_water_mgmt`	Operations-only concessions for water/wastewater utilities.
	Energy	`trans_alt_fuel`	EV charging networks and alternative fuel infrastructure.
		`power_nuclear`	Nuclear energy plants.
		`power_solar`	Solar PV arrays and solar thermal.
		`power_wind`	Onshore and offshore wind energy.
		`power_hydro_geo`	Hydroelectric, geothermal, and biomass plants.
		`power_thermal`	Natural gas turbines and fossil-fuel plants.

Continued on next page

Table A4 continued

Sector	Sub-sector	Code	Description
		`util_grid`	Transmission, distribution, and storage systems.
		`util_energy_mgmt`	Energy management and demand response programs.
	Environment	`env_resiliency`	Flood-walls, coastal restoration, and environmental remediation.

A5 Proofs

Throughout, $P = K - G_f - G_{sl}$ is the private capital requirement, $D \le \theta_c \Pi$ is the borrowing constraint of (2), and sponsor $j \in \{O, F\}$ solves (3).

Proposition 1 (Participation and structuring).

Proof. (a) Equity required is $E_c^* = P - D_c^*$. Debt is bounded above by (2), $D_c^* \le \theta_c \Pi$, so $-D_c^* \ge -\theta_c \Pi$ and therefore

$$\begin{aligned} E_c^* &= P - D_c^* \ge P - \theta_c \Pi \\ &= K - G_f - G_{sl} - \theta_c \Pi, \end{aligned}$$

the second line substituting (1). Holding the public contributions fixed, $\partial E_c^* / \partial K = 1 > 0$, so the lower bound on required equity rises one-for-one with project cost. Define $\bar{K}$ by $\bar{K} - G_f - G_{sl} - \theta_c \Pi = \bar{E}_O$. For $K > \bar{K}$ it follows that $E_c^* > \bar{E}_O$, so the operating sponsor cannot fund the equity alone and outside capital enters.

(b) Let $b(n)$ denote the benefit of dividing a given contribution across n instruments, with $b' > 0$ and $b'' < 0$, and let the arranging cost be $\kappa_j n$. Sponsor j solves

$$\max_n \; b(n) - \kappa_j n,$$

with first-order condition

$$b'(n_j^*) = \kappa_j.$$

Since $b'' < 0$, the marginal benefit b' is strictly decreasing and hence invertible, so

$$n_j^* = (b')^{-1}(\kappa_j).$$

The inverse of a strictly decreasing function is itself strictly decreasing. Therefore a lower per-tranche cost maps to a higher optimal number of tranches: $\kappa_F \le \kappa_O$ implies $n_F^* \ge n_O^*$. Intuitively, the sponsor adds tranches until the gain from one more equals its arranging cost, and a sponsor facing a lower cost stops later. (The argument treats n as continuous; with integer n the same comparison holds weakly.) □

Proposition 2 (Control).

Proof. Immediate from the equilibrium concept. The controlling sponsor selects c and then solves (3) with its own λ. A minority stake confers a claim on cash flows but no decision right, so neither the contract nor the financing choice depends on the presence of a non-controlling investor. □

Proposition 3 (Financing).

Proof. (a) For $j = F$ the objective in (3) is $V_F(D) = (\rho - r_d)D$, linear with slope $\rho - r_d > 0$, hence maximized at the largest feasible D:

$$D_F \;=\; \min\{P,\; \theta_c \Pi\}.$$

For $j = O$ the objective is $V_O(D) = (\rho - r_d)D - \lambda q(D)$, with

$$V_O'(D) = (\rho - r_d) - \lambda q'(D),$$
$$V_O''(D) = -\lambda q''(D) \; < \; 0,$$

so V_O is strictly concave and its maximizer unique. The condition $\lambda q'(0) < \rho - r_d$ gives $V_O'(0) > 0$, ruling out $D_O = 0$. The condition $\rho - r_d < \lambda q'(\theta_c \Pi)$ gives $V_O'(\theta_c \Pi) < 0$, ruling out the corner. Hence D_O is interior and solves

$$\lambda q'(D_O) = \rho - r_d, \qquad \text{with} \qquad D_O < \theta_c \Pi.$$

Therefore $D_F = \min\{P, \theta_c \Pi\} \geq D_O$, strictly when the ceiling binds for F.

(b) Take the case in which the ceiling binds for the financial sponsor, so that $\theta_c \Pi < P$ and $D_F = \theta_c \Pi$. Since $E_j = P - D_j$ for each type,

$$\frac{E_F}{P} = 1 - \frac{\theta_c \Pi}{P},$$
$$\frac{E_O}{P} = 1 - \frac{D_O}{P}.$$

Subtracting the first line from the second,

$$\frac{E_O}{P} - \frac{E_F}{P} = \left(1 - \frac{D_O}{P}\right) - \left(1 - \frac{\theta_c \Pi}{P}\right)$$
$$= \frac{\theta_c \Pi - D_O}{P} \; \equiv \; s \; > \; 0,$$

where $s > 0$ because $D_O < \theta_c \Pi$ from part (a). The operating sponsor's equity share is therefore the financial sponsor's plus the slack it leaves on the borrowing constraint,

$$\frac{E_O}{P} \; = \; \frac{E_F}{P} \; + \; s.$$

The first line depends only on the contract and the project, both common to any sponsor facing them. The slack s depends on λ and on the curvature of q, which vary across operating sponsors. Taking variances across projects,

$$\mathrm{Var}\left(\frac{E_O}{P}\right) \; = \; \mathrm{Var}\left(\frac{E_F}{P}\right) + \mathrm{Var}(s) + 2\,\mathrm{Cov}\left(\frac{E_F}{P},\, s\right).$$

Under $\mathrm{Cov}(E_F/P,\, s) = 0$ the result follows from $\mathrm{Var}(s) > 0$. The inequality is therefore not an identity: it requires genuine heterogeneity in λ across operating sponsors. Were every operating sponsor identical, s would be constant and the two dispersions would coincide. □

Proposition 4 (Selection).

Proof. Substituting the optima from Proposition 3 into the objective,

$$V_F(c) \;=\; (\rho - r_d)\,\min\{P,\ \theta_c \Pi\}.$$

Whenever $\theta_c \Pi < P$, so that the ceiling binds,

$$\frac{\partial V_F}{\partial \theta_c} \;=\; (\rho - r_d)\,\Pi \;>\; 0,$$

so that V_F is increasing in the advance rate. If the ceiling binds under both contracts, that is $\theta_A \Pi < P$ and $\theta_R \Pi < P$, then $\min\{P, \theta_c \Pi\} = \theta_c \Pi$ for $c \in \{A, R\}$ and

$$\begin{aligned} V_F(A) - V_F(R) &= (\rho - r_d)\,\theta_A \Pi - (\rho - r_d)\,\theta_R \Pi \\ &= (\rho - r_d)\,(\theta_A - \theta_R)\,\Pi \;>\; 0, \end{aligned}$$

the sign following from $\rho > r_d$, $\Pi > 0$ and $\theta_A > \theta_R$. If the ceiling binds under A only, the difference is $(\rho - r_d)(P - \theta_R \Pi) > 0$ and the conclusion is unchanged. For the operating sponsor, D_O solves $\lambda q'(D_O) = \rho - r_d$, in which θ_c does not appear, so $V_O(A) = V_O(R)$. □

Proposition 5 (Discrimination).

Proof. Write the gap under contract c as

$$\Delta(c) \;=\; \frac{D_F(c) - D_O}{P} \;=\; \frac{\min\{P,\ \theta_c \Pi\} - D_O}{P}.$$

By Proposition 3, D_O solves a condition not involving θ_c and is therefore invariant to c. Hence

$$\Delta(A) - \Delta(R) \;=\; \frac{\min\{P,\ \theta_A \Pi\} - \min\{P,\ \theta_R \Pi\}}{P} \;\geq\; 0,$$

strictly positive when $\theta_R \Pi < P$, that is, when the ceiling binds under the revenue-risk contract. If the ceiling binds under neither contract, both sponsors are interior and $\Delta(A) = \Delta(R) = 0$. □

A6 Additional Figures

Figure A2: From P3 project to private capital, by sector

This figure follows each sector's projects through the stages that define the analysis sample: all P3 projects, those that reached financial close, those that are privately financed (a delivery mode that includes private financing, or a lease-operate-maintain concession with an upfront fee), and those using a private activity bond or federal credit. Counts are printed inside the bars and each percentage is taken against the preceding bar. The stacked bar at the right of each panel shows projects that have not reached financial close, split by whether they are privately financed.

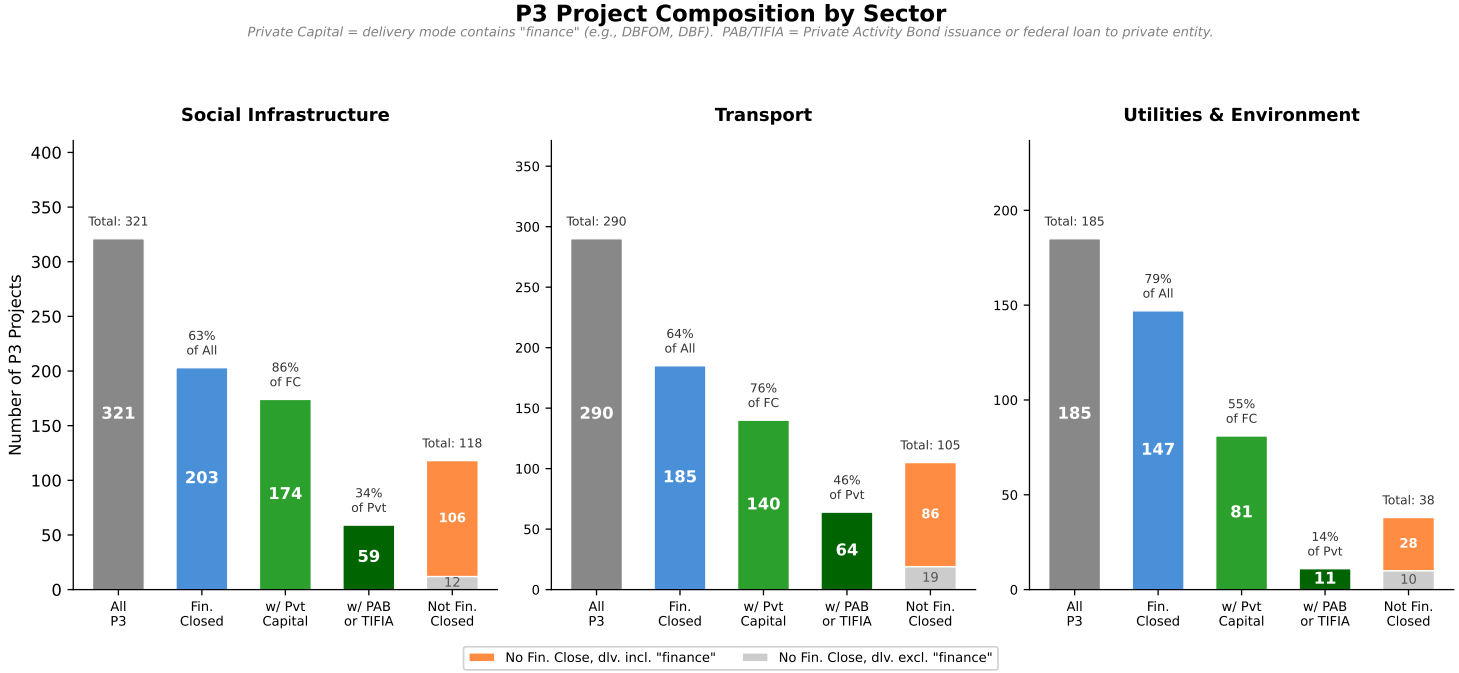
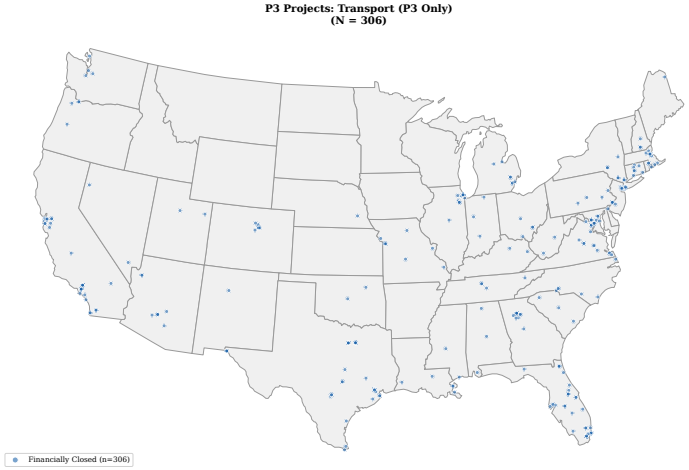
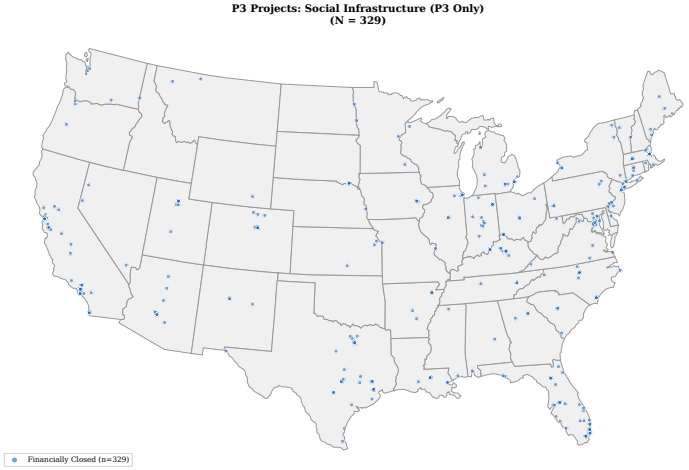


Figure A3: Geographic distribution of P3 projects by sector

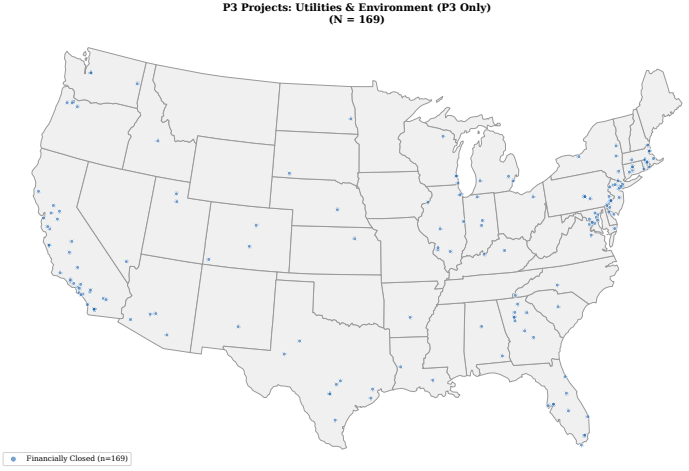
Each dot is a P3 project, placed by its recorded location. Panels are drawn separately by sector because transport projects cluster on interstate corridors while social infrastructure follows population and public university campuses.



(a) Transport



(b) Social infrastructure



(c) Utilities and environment