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Institutional Investors and Infrastructure Investing

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Institutional investors expect infrastructure to deliver long-term stable returns but gain exposure to infrastructure predominantly through finite-horizon closed private funds. The cash flows delivered by infrastructure funds display similar volatility and cyclicality as other private equity investments, and their performance similarly depends on quick deal exits. Despite weak risk-adjusted performance and failure to match the supposed characteristics of infrastructure assets, closed funds have received more commitments over time, particularly from public investors. Public institutional investors perform worse than private institutional investors. ESG preferences and regulations explain 25%–40% of their increased allocation to infrastructure and 30% of their underperformance. (*JEL* G11, G23, G28, H54, H75)

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Over the past decade, there has been a surge in the allocation of institutional investor assets to infrastructure investments. As a result, institutional investors, such as pension funds, sovereign wealth funds, endowments, and insurance companies, are becoming increasingly important alongside governments in the provision of the capital that finances infrastructure projects (Walter 2016). Part of this phenomenon is a supply-side story. As Schwartz et al. (2020) note in an overview report published by the International Monetary Fund, “infrastructure needs far exceed the resources that countries can hope to raise in a fiscally responsible and macroeconomically sustainable way.” For instance, Bennett et al. (2020) document that basic infrastructure in the United States owned by governments has aged dramatically. Such pressures have led to calls for greater recourse to private capital in infrastructure (G20 Global Infrastructure Initiative 2017; Lipshitz and Walter 2019) and a resulting increased quantity of investable infrastructure assets.

A common explanation for why institutional investor demand for infrastructure has risen so much and continues to increase is as follows: infrastructure is a new asset class with attractive attributes, such as low sensitivity to swings in the business cycle, little correlation with equity markets, and long-lasting, inflation-linked cash flows. The underlying assets in sectors such as renewable energy, traditional energy, transportation, utilities, information and communication technology (ICT), schools and hospitals have long duration, are more tangible, belong to highly regulated industries, and in some cases are even backed by long concession agreements. As such, many institutional investors consider infrastructure a natural fit with their long-duration liabilities (Della Croce 2012). The financial industry tends to support this presentation of the benefits of infrastructure investment, regulators are increasingly treating infrastructure more favorably than other private assets, and many institutional investors echo these views in their own statements of why they invest in infrastructure.[1]

But is infrastructure delivering cash flows and returns that would be consistent with this story? Infrastructure investing is organized primarily through four structures: closed private funds, direct deals, listed funds, and open-ended funds. Of these, closed private funds, which reached $486 billion

[1] Internet Appendix Figure IA.1 shows that the three most common reasons institutional investors incorporate infrastructure in their portfolios are a desire for reliable income streams, low correlation to other assets, and inflation hedging. Changes to the Swiss pension fund regulation BVV2 adopted in 2020 provide examples of more favorable regulatory treatment of infrastructure. The newly added article 55f of BVV2 separates infrastructure from other alternative assets, allows an allocation of up to 10% of total assets only to infrastructure, and imposes a joint maximum cap of 15% to all other alternative assets. The financial industry also endorses these investor expectations and favorable regulations. According to Deutsche Asset Management (2017), “infrastructure offers relatively low long-term cash flow volatility compared with other asset classes and can also provide attractive, inflation-hedged total returns. The cash flows of infrastructure assets with inherently long lives and strong intrinsic value, can provide a good match for the long-term liabilities of certain investors, such as pension funds for example.” JP Morgan Asset Management (2017) bases its case for infrastructure on “benefits of diversification, inflation protection, and yield, along with a strong focus on environmental, social, and governance (ESG) principles.”

of assets under management (AUM) as of 2019, represent the lion's share of investor commitments, and also the majority of the dollar value of deals. The second most relevant structure is the direct deal. Direct deals are implemented by a small number of deep-pocketed investors and are not currently applicable to the majority of institutional investors as they require very large commitment to a single asset as well as specialized human capital to select and monitor these assets (Fang, Ivashina, and Lerner 2015).[2]

In this paper, we analyze the risk and return characteristics of infrastructure investments, as well as the drivers of their payout policy and performance. In doing so, we test—and through our tests reject—the hypothesis that infrastructure investing through closed private funds on average delivers more stable and diversifying cash flows than other alternative asset classes. Instead, we find that infrastructure investment, as institutional investors primarily practice it, has procyclical cash flows generated largely by quick deal exits. Despite the fact that infrastructure covers long-lived tangible assets, the business model of closed funds does not translate any potential differences in the underlying assets into different risk-return properties. We provide three main points of evidence that closed end funds do not deliver on the promised characteristics of infrastructure as an asset class.

First, we study the risk-return profile of closed infrastructure funds. We calculate the average public market equivalent (PME) of infrastructure funds at 0.93, which is lower than the PMEs of buyout, venture capital (VC), and real estate funds. This measure, however, does not account for differential risk, at least in full generality (see, e.g., Gupta and van Nieuwerburgh 2021; Korteweg and Nagel 2016; Korteweg 2019; Sorensen and Jagannathan 2015). We address this in several ways. We calculate that the cross-sectional dispersion in the standard PME of infrastructure funds is 0.31, comparable with buyout and real estate funds (0.36 and 0.28), though lower than VC (0.56). We then examine the full distribution of several performance measures delivered by infrastructure funds versus other fund types. Only VC funds appear to be riskier than infrastructure, while the returns of the buyout and real estate funds have similar dispersion (and left tail) to that of infrastructure funds. Finally, we use the generalized public market equivalent (GPME) method of Korteweg and Nagel (2016) to risk-adjust the returns to infrastructure. We find that infrastructure has a GPME of -0.257, or an abnormal loss of \$0.257 per dollar invested, comparable to that of VC. Infrastructure has a market loading on the stochastic discount factor that is well above one, reflecting the fact that positive performance of infrastructure funds typically happens in times of rising markets. The aggregate stock market is not the only risk factor related to

[2] For instance, the top-20 investors in direct deals account for 55% of investor-deal observations, while the top-20 investors in closed funds account for less than 10% of investor-fund observations. U.S. institutional investors are the largest group in our sample, and they have made 2,330 commitments to closed funds, but only 175 commitments to open-ended funds, 128 commitments to listed funds, and 62 direct investments in infrastructure assets.

infrastructure returns. For instance, Gupta and van Nieuwerburgh (2021) find that closed infrastructure funds have a negative risk-adjusted profit of −6 cents per dollar invested, and the risk exposure of their cash flows can be replicated with a portfolio of listed infrastructure assets, Treasury bonds, and the aggregate stock market.

Second, we show that the risk of closed infrastructure funds is similar to the risk of other private funds, as their cash flows and returns also primarily reflect quick asset sales rather than long-term stable dividend yields. The closed fund structure in infrastructure provides incentives to exit the best performing assets quickly, similar to the incentives in other private markets (Hochberg, Ljungqvist, and Lu 2007; Sorensen 2007; Lopez-de-Silanes, Phalippou, and Gottschalg 2015). The performance of infrastructure funds is strongly positively related to the percentage of quickly exited deals. A 10-percentage-point increase in exited deals in the first 5 years is associated with a 0.085 higher PME, a 2.575-percentage-point higher IRR, and a 0.079 higher multiple of invested capital. Even though infrastructure funds hold tangible assets frequently backed by concession agreements, the incentives of closed funds seem incompatible with the investors' expectations of stable long-lasting income streams.

Third, we show that similar to other private funds, infrastructure funds deliver procyclical cash flows. Following the methodology of Robinson and Sensoy (2016), we find that the net cash flows delivered by infrastructure funds are high when the price-dividend ratio is high and when the yield spread is low. The sensitivity to changes in the market conditions is similar to the sensitivity of other alternative asset classes. Furthermore, we adapt the methodology from Robinson and Sensoy (2016) to examine how cash flow volatility is affected by including infrastructure funds in a portfolio of buyout or VC funds. The only marginal improvement in cash flow volatility to a buyout fund portfolio appears to be the addition of VC funds (and vice-versa). Increasing the number of funds matters of course for reducing idiosyncratic volatility, but we do not detect any additional benefit in terms of cash flow volatility from diversifying across fund types into infrastructure.

Despite both weak performance and the failure to match the supposed characteristics of infrastructure investments, closed infrastructure funds have increased their assets under management from $59 billion in 2008 to $486 billion in 2019. Other alternative asset classes, such as private equity and hedge funds, showed initial years of successful returns by a smaller group of institutional investors, such as endowments, before growing rapidly in assets under management more generally (see, e.g., Dichev and Yu 2011; Sensoy, Wang, and Weisbach 2014; Ivashina and Lerner 2019). Why then have private infrastructure investments increased dramatically despite this evidence of relatively weak performance?

To shed light on this question, we examine which investors have contributed most to the growth of infrastructure as an asset class and the objectives of these investors. Specifically, we consider the number of investments in infrastructure by institutional investors as a function of whether the investor is a public entity (public pension funds, sovereign wealth funds, and government agencies), as well as variables related to Environmental-Social-Governance (ESG) considerations. Such investors may be willing to accept lower performance in return for social externalities.

We find that public investors increase their exposure to closed fund infrastructure investments more over time than private investors. Furthermore, while United Nations Principles for Responsible Investment (UN PRI) signatories make more infrastructure investments, as do institutional investors subject to ESG regulatory mandates, public investors are especially likely to increase their infrastructure investments conditional on these ESG shocks. Public investors that have signed the UN PRI make 0.759 more infrastructure investments per year as compared to investors that have not signed the UN PRI. Interaction terms suggest that UN PRI adoption and shocks imposing voluntary ESG regulations on public investors explain around 25%–40% of the higher number of infrastructure investments made by public investors.

While closed infrastructure funds overall deliver relatively low risk-adjusted performance, public investors have even lower performance than private investors. Public investors receive a 0.026 lower PME, a 1.810 percentage points lower IRR, and a 0.038 lower multiple of invested capital than private investors. If the expected real return on infrastructure is similar to the equity risk premium and around 5% (Graham and Harvey 2005; Andonov and Rauh 2020), the lower IRR of public investors implies that the underperformance of these investors amounts to approximately 30% of the expected real return. The differences in performance between public and private investors do not seem to be due to differences in risk-taking, as we control for the characteristics of the underlying deals, such as project stage (greenfield, brownfield, secondary), region, and industry (e.g., renewable energy, traditional energy, social, transport, and utilities). These deal-level controls address the possibility that public investors gain exposure to less risky assets that will deliver lower returns. The underperformance of public investors is also not driven by "home deals," which we define as deals in the same country or U.S. state of the institutional investor.[3] Home deals have lower exit rates, but this relation holds for public as well as private investors, and controlling for home deals does not explain the underperformance of public investors in infrastructure.

We hypothesize that the underperformance of public investors is at least partially driven by the stronger social externalities of infrastructure assets. Prior research has already documented that public institutional investors underperform due to politicized governance structures and unskilled board members (Bortolotti, Fotak, and Megginson 2015; Bradley, Pantzalis, and Yuan 2016;

[3] Hochberg and Rauh (2013) demonstrate that U.S. institutional investors exhibit home-state bias as they are more likely to invest in private equity funds raised by local general partners.

Andonov, Hochberg, and Rauh 2018), an inability to compensate and attract talented staff members (Dyck, Manoel, and Morse 2019), systematically unfavorable fee arrangements (Begenau and Siriwardane 2020), and an inability to select or access better-performing asset managers (Lerner, Schoar, and Wongsunwai 2007; Sensoy, Wang, and Weisbach 2014; Cavagnaro et al. 2019). Our contribution is to examine a new social externalities channel that negatively affects the financial performance of institutional investors with nonfinancial objectives. Infrastructure assets have the potential to offer environmental, social, and political benefits, and we find that public institutional investors with strong ESG preferences or regulatory pressure invest more in infrastructure over time. If these public investors have a higher allocation to infrastructure due to regulation or impact investing, they may take on more marginal deals in order to meet their nonfinancial objectives which will lead to underperformance (Barber, Morse, and Yasuda 2021).

Controlling for ESG preferences, especially UN PRI adherence and whether a fund is an impact fund, explains around one-third of the public investor underperformance in infrastructure relative to private investors. Our results therefore imply that ESG considerations and a focus on sustainability and impact investing contribute to increased infrastructure investment overall, and in particular by public institutional investors, but also to the underperformance of public institutional investors. We emphasize that the granularity of our data allows for the use of deal characteristics, such as project stage, location, industry, and concession agreement, as controls that capture the riskiness of the underlying assets in performance regressions as well as preferences for investing in certain types of infrastructure assets. Our results do not imply that UN PRI signatories and impact investors underperform because they invest in renewable energy or emerging economies, but rather that their underperformance seems to be due to investing in marginal deals within these industries or regions that have a lower financial return and may not have received funding from traditional infrastructure funds. Barber, Morse, and Yasuda (2021) document willingness-to-pay for impact by some investors in VC, but the volume of institutional capital driven by nonfinancial objectives is significantly higher in infrastructure.

Our paper offers several implications for infrastructure as an asset class and private markets in more general. First, we contribute to the literature on the performance of alternative assets, which primarily focuses on private equity, commercial real estate and housing (see, e.g., Kaplan and Sensoy 2015; Chambers, Spaenjers, and Steiner 2021; Eichholtz et al. 2021; Gupta and van Nieuwerburgh 2021; Sagi 2021), and extend it by studying infrastructure.[4] While the closed fund structure in private equity delivers productivity gains

[4] Van Nieuwerburgh, Stanton, and de Bever (2015) also examine infrastructure. They mainly focus on the risks and returns of listed infrastructure investments, while we study the dominant role of private closed infrastructure funds.

and the opportunity for rapid restructuring (see, e.g., Davis et al. 2014), we find that other investment structures, such as listed funds, open-ended funds, and direct deals, hold assets longer and may be better designed to provide long-term exposure to tangible infrastructure assets with stable cash flows. Recent evidence shows that pension plan members have persistent social preferences for sustainability (Bauer, Ruof, and Smeets 2021), and institutional investors plan to address ESG risks, such as climate change, through long-term engagement strategies (Krueger, Sautner, and Starks 2020). Thus, the closed fund structure is not ideal for meeting long-term nonfinancial objectives either. The development of infrastructure as an asset class in the long run depends on establishing an investment structure that takes into account the specific nature of the desired underlying assets and investor objectives, rather than just copying the traditional private equity model.

Second, the social externalities channel is relevant especially for assets closely related to government spending and regulation but managed by profit-maximizing intermediaries. Prior literature on the higher education, prisons, and health sectors has identified situations in which consumers bear the costs of increased profit-maximizing incentives of private funds through worse services (Eaton, Howell, and Yannelis 2020; Gupta et al. 2020; Mukherjee 2021). Our contribution to this literature is to show that public institutional investors may also pick up part of the bill by accepting lower returns when investing in assets characterized by positive externalities and government involvement. While infrastructure investments could clearly have societal benefits, the underperformance reflects a price that is paid to create these benefits, with the transfers going either to the infrastructure assets or to the general partners (GPs) through fees. We estimate the annual dollar value of these transfers to be around $5 billion.

Third, the failure of closed funds to match investor expectations and the underperformance of public investors imply that over a long horizon infrastructure runs the risk of not being able to attract sufficient capital in competitive private markets, and institutional investors will not be willing to cover the infrastructure funding gap. To the extent that infrastructure targets specific assets essential for competitiveness and long-run potential economic growth (Fernald 1999; Roller and Waverman 2001; Esfahani and Ramirez 2003; Donaldson 2018), our findings have far-reaching implications. Furthermore, private involvement in infrastructure may reduce the amount of wasteful spending, the political direction of flows, and the corruption associated with government infrastructure programs (Castells and Sole-Olle 2005; Cadot, Roller, and Stephan 2006; Olken 2007; Schwartz et al. 2020).

1. The Characteristics of Infrastructure Funds and Deals

To study the characteristics of infrastructure as an asset class, we obtain data on the equity positions of institutional investors in infrastructure assets from

Preqin (we do not analyze infrastructure debt providers). The Preqin database identifies the institutional investors that commit capital to infrastructure funds as well as the underlying deals completed by these funds. An alternative data source is Burgiss, which is arguably the most comprehensive high-quality data of fund cash flows, but it does not provide information on the identity of investors or underlying deals. Gupta and van Nieuwerburgh (2021) and Harris, Jenkinson, and Kaplan (2014) show that the performance of private funds reported in Preqin is qualitatively similar to that in Burgiss. Our analysis relies on Preqin data, but we also compare the performance of infrastructure funds reporting in Preqin with the funds reporting in Burgiss. The sample includes infrastructure investments from January 1990 until June 2020, but the vast majority of investments happens during the 2008-2020 period when infrastructure developed as an asset class.

We collect the investments made by six types of institutional investors. Three types of investors belong to the public sector: public pension funds, government agencies, and sovereign wealth funds. We classify also development banks as government agencies, so our sample of government agencies includes the International Finance Corporation, European Investment Bank, and U.K. CDC Group, among others. The other three types of investors belong to the private sector: private pension funds, insurance firms and banks, and university endowments and foundations. Figure 1 depicts the investment structures through which investors can gain equity exposure to infrastructure. Our sample contains 1,861 institutional investors from 69 countries, plus several international financial institutions which are classified as international instead of being assigned to one country. Investors can invest in infrastructure assets directly or through different types of funds run by GPs. Our sample covers 5,920 commitments of investors to infrastructure funds and 2,049 direct investments in assets. Directly and through funds, institutional investors gain exposure to 5,907 unique infrastructure assets. There may be multiple deals (transactions) in a given asset during the sample period. Since infrastructure funds invest in multiple deals and collect commitments from multiple investors, our sample contains 82,070 investor-deal observations.[5]

Institutional investors make commitments to 633 unique funds managed by 301 unique GPs. When investing through infrastructure funds, institutional investors can select between three fund types: closed, listed, and open-ended funds. The 5,920 commitments to infrastructure funds consist of 5,189 commitments to 538 closed funds, 271 commitments to 49 listed funds, and 460 commitments to 46 open-ended funds. Thus, the vast majority of investors gain

[5] We compare the coverage of Preqin with the Capital IQ data set. From the total of 5,920 investor-fund observations, 746 appear in both Preqin and Capital IQ, 4,987 appear only in Preqin, and 187 appear only in Capital IQ. Thus, we expand our Preqin sample by incorporating the 187 additional investor-fund observations from Capital IQ. Overall, the Preqin data are more comprehensive, and we verify for several large pension funds and government agencies that the investor-fund observations that appear only in Preqin also appear in the annual reports of these investors.

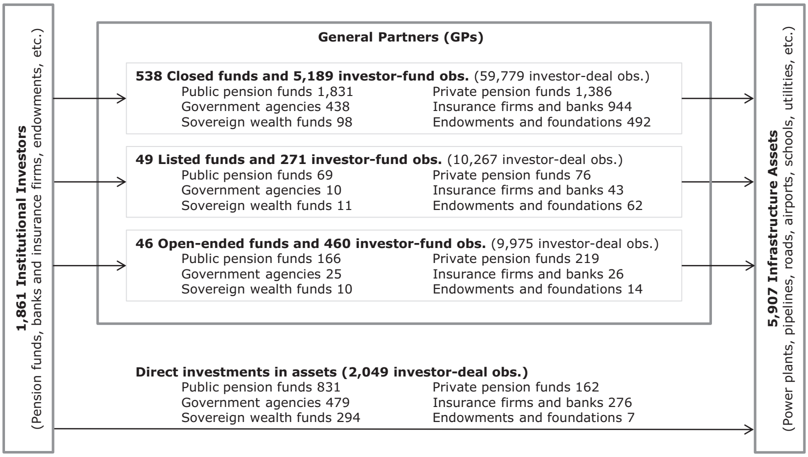

Figure 1
Investing in infrastructure
This figure depicts the investment structures through which institutional investors gain exposure to infrastructure assets. Investors can invest in infrastructure directly or through three different types of funds run by general partners, closed funds, listed funds, and open-ended funds. For every investment approach, we present the total number of investor-fund or investor-deal observations as well as the number of observations by investor type.

exposure to infrastructure assets through closed funds which are organized in a similar way as buyout and VC funds.[6] These funds are raised for a specified period (typically 10 to 12 years, with possible short extensions) and are governed by partnership agreements between the investors and the GPs. Institutional investors act as limited partners (LPs) and commit capital at the fund's start, referred to as the vintage year. Closed funds account for 59,779 investor-deal observations.

The remaining investor-fund observations are split between listed and open-ended funds. Listed infrastructure funds have publicly traded shares. Institutional investors can gain exposure to the underlying assets by buying shares of listed funds instead of signing a partnership agreement. Open-ended (evergreen) funds are not publicly traded, but they do offer more liquidity to the investors through periodic subscriptions and redemptions. Importantly, unlike closed funds, both listed and open-ended funds do not have a clear termination date and may be better designed to provide long-term exposure to infrastructure

[6] These statistics show that closed funds are the main investment structure in infrastructure, but one potential worry is that the high number of investor-fund relations might not translate into the same proportion of dollar commitments. To address this concern, we also analyze the Preqin data on the commitment amounts to closed and open-ended funds. While Preqin data on dollar commitments are sparsely populated for private investors, the data on commitments are nearly complete for U.S. and U.K. public investors, covering 85% of their investments. Internet Appendix Figure IA.2 shows that closed funds are an order of magnitude more important than open-ended funds also in dollar terms.

assets. Based on their contracts, closed funds are expected to focus more on exiting positions in assets.[7]

Table 1 and Figure 1 show that the largest groups of institutional investors are public and private pension funds, with a share of 35.2% (28,858 of 82,070) and 30.9% (25,384 of 82,070) of the investor-deal observations, respectively. Government agencies and sovereign wealth funds account for 5.6% and 2.1% of our sample of investor-deal pairs. Insurance firms and banks represent 15.7% of the sample, and endowments and foundations represent the remaining 10.5%. Panel A of Table 1 shows that institutional investors have an average of $50.36 billion in AUM with substantial cross-sectional variation across investor types, and invest on average in 3.27 funds and 1.10 direct deals. Through funds and direct investments, institutional investors gain exposure to an average of 48.16 deals.[8]

Our statistics in Figure 1 indicate that sovereign wealth funds and government agencies are more likely to invest directly in infrastructure assets, but all other institutional investors primarily rely on infrastructure funds as intermediaries. When investing through funds, there is no large cross-sectional dispersion in investment approach choices, as all institutional investors commit capital predominantly to closed funds. Public pension funds gain exposure to infrastructure assets in a similar way as private pension funds, insurance firms, banks, endowments and foundations.

A unique aspect of the Preqin data set relative to other data sets on private markets is the information on the characteristics of the underlying deals, which is presented in panel B of Table 1. Infrastructure deals can be classified into three categories based on project stage: greenfield, brownfield, and secondary stage. The greenfield category refers to assets that did not previously exist, so that investors finance the construction of the asset. The brownfield category covers assets that may be partially operational and generate income, but require substantial improvements or expansion. The secondary category includes fully operational assets that require no further investment for development. Thus, greenfield and brownfield projects are considered riskier and do not generally distribute cash flows back to the investors in the initial years of an investment. In our sample, around 73.5% of the investor-deal observations represent exposure to secondary deals. Greenfield projects account for 18.1% and brownfield projects account for 8.4% of the investor-deal observations. The exposure to

[7] Investors can also access infrastructure deals through funds-of-funds. In Preqin, we do not observe the portfolio of funds selected by funds-of-funds, and we cannot link the investor to the underlying deals. Therefore, we exclude pure funds-of-funds from the analysis, but we keep in the sample a small number of funds-of-funds that have some direct exposure to infrastructure assets in addition to the portfolio of fund investments.

[8] In Internet Appendix Tables IA.2, we list the number of investors by country and split them into public and private investors. U.S. investors are the largest group in the sample with 765 unique institutions, followed by 189 U.K, 92 Australian, 79 Canadian, and 56 German investors. In Internet Appendix Tables IA.3, we replicate Table 1 for the subsample of U.S. institutional investors, which account for 40% of our sample.

Table 1
Summary statistics

	All	Public investors			Private investors		
		Public pension funds	Government agencies	Sovereign wealth funds	Private pension funds	Insurance firms and banks	Endowments and foundations
A. Statistics on an institutional investor level							
#Investors	1,861	409	183	37	569	338	325
Investor size	50.36	25.21	93.11	162.66	10.51	158.24	2.75
Year of first investment	2008	2008	2008	2009	2007	2008	2007
#Funds	3.27	5.04	2.56	4.15	3.12	3.05	2.03
#Direct deals	1.10	2.03	2.62	7.95	0.29	0.82	0.02
#Deals	48.16	74.76	28.38	45.84	47.54	42.92	30.34
B. Distribution of investor-deal observations							
#Investor-deal obs.	82,070	28,858	4,626	1,696	25,384	12,920	8,586
Secondary	60,283	21,903	2,622	1,261	19,261	9,237	5,997
Greenfield	14,862	4,762	1,569	317	3,986	2,576	1,654
Brownfield	6,925	2,193	435	118	2,137	1,107	935
No concession	73,282	25,685	3,828	1,449	22,762	11,495	8,063
With concession	8,788	3,173	798	247	2,622	1,425	523
Renewable energy	23,172	8,423	1,931	401	6,238	3,827	2,352
Traditional energy	22,940	7,088	732	427	7,091	3,554	4,048
Transport	15,043	5,026	1,070	450	5,441	2,126	930
Social	10,151	4,346	283	114	2,979	1,762	667
Utilities	6,028	2,108	267	172	2,307	798	376
Telecoms	4,450	1,756	329	123	1,234	816	192
Diversified	286	111	14	9	94	37	21
Western Europe	35,424	14,195	1,904	528	10,615	6,117	2,065
Northern America	28,435	8,990	296	386	9,073	4,455	5,235
Latin America	5,964	2,239	488	168	1,804	551	714
Asia	5,148	1,349	797	369	1,138	1,240	255
Oceania	3,904	1,149	147	135	2,066	177	230
Eastern Europe	1,896	656	390	48	518	237	47
Africa	1,299	280	604	62	170	143	40
C. Statistics on an investor-deal level							
#Investors in deal	1.61	1.60	1.76	1.92	1.66	1.57	1.43
%Investment stake	0.63	0.62	0.57	0.55	0.61	0.66	0.71
%Total stake	0.78	0.77	0.76	0.75	0.76	0.80	0.83

In panel A, we report summary statistics on an institutional investor level. *Investor size* presents the average assets under management ($ bil.) and *Year of first investment* is the year of the institution's first investment in infrastructure. *#Funds* and *#Direct deals* measure the average number of investments in infrastructure funds and direct deals by investor. *#Deals* reports the average number of deals to which an investor gains exposure (investing through funds exposes an investor to multiple deals). In panel B, we report the distribution of investor-deal observations by deal characteristics. We show the number of observations by project stage (greenfield, brownfield, and secondary stage), concession agreement, industry, and regional location of the asset. In panel C, we report statistics on the investor-deal level. *#Investors in deal* counts the average number of investors in the same deal (but institutions investing through the same fund are not counted multiple times). *Investment stake* measures the average investment stake of the investor, while *Total stake* is the average stake of all investors in the deal.

different project stages generally does not differ across investor types, although government agencies are more likely to invest in greenfield projects.

Next we present summary statistics on whether a deal involves a concession agreement with the government, which give an exclusive right to the investor to build, operate and maintain an infrastructure asset for a given number of years.

We classify as a concession only the first transaction of an asset in which the government is directly involved as a counterparty. We do not consider resale transactions to be a concession deal, as the government is not directly involved in the transaction. We find that on average 10.7% of the investor-deal observations are backed by an initial concession agreement.

We classify the deals into seven industries. The largest industry is renewable energy and it captures investments in wind, solar, hydro, biomass, and geothermal power facilities. Traditional energy includes investments in coal and nuclear plants, natural resources pipelines, refineries, and storage facilities. The transportation industry includes investments in toll roads, parking lots and service stations, tunnels, bridges, railroads and rolling stocks, airports and aircrafts, sea ports, shipping vessels, and logistics. Social infrastructure combines investments in hospitals, medical facilities, senior homes, student accommodation, education facilities, public buildings, prisons, defense accommodation, and police stations. The utilities industry includes investments in water treatment plants, water distribution, power distribution, sewage treatment plants, sewage networks, and waste management. The telecom industry covers investments in mobile phone, landline phone, wireless, internet, cable television, and satellite networks. The final category covers diversified infrastructure projects. Overall, the infrastructure asset class encompasses projects from different industries, highlighting the importance of controlling for industry type in our analysis.

We capture differences in geographical location by classifying the assets into seven regions: Northern America (USA and Canada), Latin America and Caribbean, Western Europe, Eastern Europe, Asia, Africa, and Oceania. Around 85% of the exposure of public pension funds, private pension funds, insurance firms, banks, endowments and foundations is allocated to deals in developed markets and 15% is allocated to deals in emerging markets. Government agencies and sovereign wealth funds invest relatively more in projects located in emerging markets.[9]

Panel C of Table 1 reports summary statistics on the number of investors and ownership structure on an investor-deal level. *#Investors* counts the number of investors in the same deal. When constructing this variable, we count multiple LPs investing through the same infrastructure fund only once. On average, there are 1.61 investors in a deal, and larger transactions are typically jointly executed by multiple investors. *Investment stake* measures the average investment stake of the infrastructure fund through which the LPs accessed the deal. *Total stake* is the aggregate stake of all investors in the deal. Investors on average obtain 63%

[9] Our sample includes 5,907 unique assets located in 135 countries. In Internet Appendix Tables IA.4, we tabulate the unique assets by country. These are the five countries with the most deals: 1,374 in United Kingdom, 1,106 in United States, 331 in France, 294 in Canada, and 261 in Australia. In Internet Appendix Tables IA.5, we display the number of U.S. assets by state and industry. The three states with the most deals are Texas with 198, California with 131, and Pennsylvania with 57 deals.

ownership in the underlying asset and all investors jointly have 78% ownership in the underlying asset.

2. Assessing the Risk and Return Properties of Infrastructure

Why do institutional investors invest in infrastructure? Using the Preqin Investor Outlook surveys run in 2018, 2019, and 2020, we collect data on the investor responses to the question about the "main reasons for investing in alternative assets." Internet Appendix Figure IA.1 presents the average number of respondents selecting each of the offered options during these 3 years for three alternative asset classes. Based on these surveys, institutional investors have different expectations for infrastructure investments as compared to their expectations for private equity (a category that includes both buyout and VC). The main reasons institutional investors incorporate infrastructure into their portfolio are a desire for reliable income streams and inflation hedging. Investors expect relatively more diversification benefits and reduced volatility from the infrastructure asset class, which stands in sharp contrast to investor expectations of high absolute return and high risk-adjusted return from private equity. In addition, investors often describe infrastructure assets as a match for their long-term liabilities. Internet Appendix Tables IA.1 provides a compendium of statements made by U.S. public pension funds in their annual reports that repeat these expectations. We also list their commitments, which indicate that U.S. public pension funds intent to meet their stated objectives primarily by allocating capital to closed funds. In sum, institutional investors incorporate infrastructure into their portfolios under the stated expectation that it will deliver steady cash flows and diversification benefits due to low correlation with other asset classes.

Consistent with these institutional investor perceptions, the asset management industry promotes infrastructure as a new asset class that will deliver stable cash flows with a low correlation with the business cycle (Deutsche Asset Management 2017; JP Morgan Asset Management 2017). Regulators also have begun to perceive infrastructure investments as different from private equity for similar reasons. For example, in 2017, amendments to the EU Solvency II Delegated Regulation on insurance firms reduced the amount of capital which insurers must hold against the equity of qualifying infrastructure projects. Unlisted infrastructure equity investments have a risk calibration of 30% of their value, compared to 49% for other unlisted equities (European Commission 2017). Further, in 2020, the investment regulation of Swiss pension funds (BVV2) separated infrastructure from other alternative assets, allowed an allocation of up to 10% of total assets separately to infrastructure, and imposed a joint maximum cap of 15% on all other alternative assets (Serenelli 2020). Also in 2020, the U.K. Treasury in a review of regulation stated one objective of the review would be to "support insurance firms to provide long-term capital to underpin growth, including investment in infrastructure." Government regulators therefore are increasingly providing evaluations of infrastructure investment that parallel those of both the financial sector and institutional investors (HM Treasury 2020).

When analyzing the risk and return properties of infrastructure, we focus primarily on closed funds, as this is the main structure through which institutional investors plan to meet these expectations. Based on Figure 1, the second most important investment structure is direct deals, as listed and open ended funds are significantly smaller. The closed fund structure is highly relevant not only because it is the main investment structure but also because we would hypothesize that its scale and ability to diversify across assets makes it more suitable to greenfield and brownfield projects that actually create new infrastructure. We provide further evidence on the relative importance of closed funds and direct deals in the three ways as follows.

First, direct deals are relevant only for a few large institutional investors. Internet Appendix Tables IA.6 shows that there is substantial concentration in direct deals, as the top-20 investors in direct deals account for 55% of the investor-deal observations (the list includes primarily Canadian pension funds, Dutch pension funds, and sovereign wealth funds). The concentration among direct deals is much higher than the concentration among fund investors, as the top-20 investors in infrastructure funds account for less than 10% of the investor-fund pairs. These statistics suggest that direct investing is not applicable for the majority of institutional investors, as greater financial commitment to a single asset and specialized human capital are required to select, manage, and monitor these assets (Fang, Ivashina, and Lerner 2015).[10]

Second, in Table 2, we examine whether the different investment structures provide exposure to different types of deals. The unit of observation is the fund-deal level for deals executed by infrastructure funds and investor-deal level for deals executed directly by institutional investors. In panel A, we estimate logit regressions and the dependent variables are indicators for project stage, concession agreement, and industry of the deal. We find that direct investors, listed funds, and open ended funds are significantly less likely to gain exposure to greenfield and brownfield projects, so their portfolios consist predominantly of secondary deals. For instance, the unconditional probability of investing in a greenfield deal is 25.2%, while direct investors, listed funds, and open-ended funds have a 5.0%, 11.1%, and 10.9% lower probability of investing in greenfield deals, respectively. We also document that direct deals invest more in traditional industries, such as transport and utilities, and have a lower exposure to renewable energy assets. This analysis suggests that closed funds are more

[10] Recently, institutional investors have started forming consortia, which may be an important route for smaller investors who wish to reduce intermediation costs but who are unable to establish a direct investment division individually. These vehicles are in our sample, and we classify them as direct investors. In the future, as such structures grow in popularity, it would be valuable to analyze separately the performance, organization, and governance of investors' consortia in infrastructure.

Table 2
Deal type and investment structure

A. Deal project stage and industry

	Greenfield (1)	Brownfield (2)	Secondary (3)	Concession (4)	Renewable energy (5)	Traditional energy (6)	Transport (7)	Utilities (8)
Unconditional prob.	0.252	0.084	0.664	0.160	0.358	0.173	0.196	0.065
Direct deal	−0.050**	−0.034***	0.083***	0.025	−0.115***	−0.031*	0.118***	0.051***
	[0.025]	[0.010]	[0.029]	[0.025]	[0.037]	[0.018]	[0.025]	[0.014]
Listed	−0.111***	−0.052***	0.165***	−0.021	0.107	−0.125***	−0.019	−0.030**
	[0.036]	[0.019]	[0.042]	[0.035]	[0.078]	[0.022]	[0.035]	[0.014]
Open ended	−0.109***	−0.045***	0.157***	−0.049	0.106	−0.005	−0.006	0.034
	[0.038]	[0.014]	[0.042]	[0.035]	[0.105]	[0.035]	[0.042]	[0.024]
Vintage FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Deal region FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	8,665	8,649	8,665	8,651	8,591	8,652	8,651	8,595

B. Deal investment stake and size

	#Investors (1)	Investment stake (2)	Deal size (3)	Investment size (4)
Direct deal	1.151***	−0.299***	0.916***	0.237**
	[0.115]	[0.023]	[0.106]	[0.109]
Listed	−0.277***	−0.012	−1.098***	−0.830***
	[0.075]	[0.027]	[0.205]	[0.194]
Open ended	0.052	−0.029	0.059	0.003
	[0.148]	[0.053]	[0.267]	[0.243]
Vintage FE	Yes	Yes	Yes	Yes
Deal region FE	Yes	Yes	Yes	Yes
Deal industry FE	Yes	Yes	Yes	Yes
Observations	8,666	8,172	3,131	3,131
R-squared	.196	.292	.333	.270

In this table, observations are at the fund-deal level for transactions executed by infrastructure funds and investor-deal level for transactions executed directly by institutional investors. *Direct deal* is an indicator variable for direct investments in infrastructure deals. *Listed* and *Open ended* are indicators for deals accessed through listed and open-ended funds. The omitted investment structure is closed funds. Panel A presents the results of logit regressions in which the dependent variables are different deal characteristics. In these logit regressions, we present the average marginal effects, which for our indicator variables are estimated for a change from zero to one. Above the regressions, we also show the unconditional probability for all dependent variables. In columns 1, 2 and 3, the dependent variables *Greenfield*, *Brownfield*, and *Secondary* are indicators for the three project stages. In column 4, the dependent variable *Concession* equals one if a fund or direct investor enters a concession agreement with the government. In columns 5 to 8, the dependent variables are indicators for deals in renewable energy, traditional energy, transport, and utilities industry, respectively. Panel B presents results of OLS regressions. In column (1), the dependent variable *#Investors* counts the total number of investors in the same deal. In column (2), the dependent variable *Investment stake* is the ownership stake of an infrastructure fund or direct investor. In column (3), *Deal size* measures the natural logarithm of the total transaction amount in $ mil. In column 4, *Investment size* is the natural logarithm of the investment size and is calculated by adjusting the deal size for the investment stake. We include vintage year fixed effects and control for the deal region fixed effects (also deal industry fixed effects in panel B). We cluster standard errors by infrastructure fund (institutional investor for direct deals) and report standard errors in brackets. * $p<.1$; ** $p<.05$; *** $p<.01$.

likely to create new infrastructure assets and address the government demand for infrastructure funding (Bennett et al. 2020; Schwartz et al. 2020).

Third, in Table 2, panel B, we also conclude that direct investors participate in deals with multiple investors (column 1) and take around a 30% lower investment stake (column 2) than an infrastructure fund would take, which means that direct investors frequently take a minority stake in the assets. The main implication is that direct investors do not lead infrastructure investments, but rather provide deep pockets for larger transactions. Based on column 4, direct deals have a larger investment size than deals of closed funds. The difference in mean investment size (not logs) is around $200 million. Our sample decreases when analyzing deal size because this variable is sparsely populated in the Preqin data set. We do not know the size of the missing deals, but the sample loss is comparable across all four investment structures.

Overall, closed funds are the most relevant investment structure for the majority of investors. Next, we study the risk and return characteristics of these closed infrastructure funds by analyzing cash flow data to gain a complete picture of the performance and payout policy of private funds (see, e.g., Harris, Jenkinson, and Kaplan 2014; Korteweg and Nagel 2016; Ang et al. 2018; Gupta and van Nieuwerburgh 2021). In Table 3, we compare the performance of investments in closed infrastructure funds with investments in buyout, VC, and real estate funds, for the subsample of funds for which Preqin contains performance data over the period 2002–2018. The comparison is based on three performance measures: the public market equivalent (PME) calculated as in Kaplan and Schoar (2005), the net internal rate of return (IRR), and the net multiple of invested capital.[11] The PME is generally viewed as a superior performance statistic relative to the commonly reported IRR and multiple, because the PME compares the cash flows generated by the private investments to those of a benchmark asset, such as the stock market, by dividing the present discounted value of fund distributions plus any remaining residual value by the present discounted value of capital calls.[12] However, the PME calculation is more demanding from a data perspective, as it requires a vector of the cash flows over time for each fund, and this is generally only available for a subset of the funds for which the other performance statistics are reported.

During the 2002–2018 period, of the full fund sample there were 315 funds for which Preqin reported a multiple, 210 for which Preqin reported an IRR, and 157 for which we were able to obtain from Preqin cash-flow data that allow for the calculation of the PME.[13] The number of infrastructure funds is smaller than the number of funds raised in the other private asset classes, but infrastructure funds are relatively large. Table 3 indicates that the average size of a closed infrastructure fund in our sample is $1.35 billion and the median is

11 These measures are also not all final as only 43 of the funds with available performance data are fully realized. For recent funds, in addition to the cash flows that are actually distributed to investors, all three of these performance measures depend, to some extent, on the reported estimate of residual value in the infrastructure fund.

12 Unlike the IRR measure, the PME approach adjusts for market movements and is robust to variations in the timing and systematic risks of the underlying cash flows as well as potential manipulations by GPs (see, e.g., Kaplan and Schoar 2005; Kaplan and Sensoy 2015; Sorensen and Jagannathan 2015).

13 Preqin collects data on performance primarily via Freedom of Information Act requests submitted to public investors, who invest in funds that private investors also invest in, as well as voluntary provision of performance information by other investors. In Table 4, we study performance reporting as a function of deal exits and other deal characteristics that are universally available for all deals in the sample, and we return to this issue later in the paper when we study the performance of infrastructure investments as a function of the type of LP.

$0.72 billion. Infrastructure funds are on average similar to buyout funds, two times larger than real estate funds, and four times larger than VC funds.

We use the S&P 500 stock market index as the reference asset to calculate the PMEs for the infrastructure funds. As shown in panel B of Table 3, infrastructure funds have underperformed the public market with an average PME of 0.93, or a present value of the underperformance equal to 7.0% of the total present value of paid-in capital over the life of the fund. The average PMEs delivered by buyout, VC, and real estate funds in the same time period are 1.05, 0.99, and 0.94, respectively. The other performance measures, IRR and multiple of invested capital, also suggest that infrastructure delivers relatively low returns compared to the other private asset classes.[14]

More importantly, even though investors may incorporate infrastructure in their portfolios due to expected stable (less risky) cash flows, the standard deviations of the performance of infrastructure funds are very similar to the standard deviations of buyout and real estate funds. For example, the PME of infrastructure funds has a standard deviation of 0.31, which is comparable to the standard deviation of 0.36 and 0.28 that buyout and real estate funds provide. Only VC funds stand out as a riskier asset class with higher standard deviations on all performance measures.

Figure 2 extends the performance analysis by presenting the distribution of performance. If infrastructure delivers more stable cash flows by providing exposure to less risky investments, it should have a narrower distribution of performance, and the lowest and highest performance percentiles should be closer to the mean (or median) performance. However, Figure 2 shows that the distribution of returns delivered by infrastructure funds is as wide as the distribution of returns delivered by buyout and real estate funds. Only VC funds appear to be riskier, while the returns of the other types of private funds appear to have a similar dispersion (and left tail) to that of infrastructure funds. This conclusion holds across all three performance measures.[15]

In panel C of Table 3, we compare the performance statistics reported in Preqin with the performance statistics available in Burgiss. The total number of infrastructure funds covered in Burgiss is smaller, but these are relatively larger funds. Furthermore, Burgiss contains more fund cash flow data, which enables us to examine the PME across a broader sample of funds. Infrastructure funds reporting in Burgiss have a lower performance based on all three measures, which suggests that if anything, the performance measures in Preqin may be upward biased. We address this upward bias in our analysis (see Table 4) by studying which funds report performance in Preqin. Importantly, the standard

[14] We note that since multiples are not adjusted for the time horizon over which the investment has taken place, the fact that some of the funds in this calculation have been raised recently and not fully liquidated likely depresses the multiple for all fund types.

[15] It is known that the distribution of PMEs can be affected by fluctuations in the underlying stock market benchmark index used to discount the cash flows. Therefore, even asset classes with stable cash flows could have a wide distribution of PMEs. However, multiples and IRRs are not affected by this critique, as they are not benchmarked.

Table 3
Comparison of the performance and cash flows of infrastructure funds with other private funds

	Infrastructure				Buyout				Venture capital				Real estate			
	Funds	Mean	Median	SD	Funds	Mean	Median	SD	Funds	Mean	Median	SD	Funds	Mean	Median	SD
A. Fund size in $ bil.																
Preqin	315	1.35	0.72	1.86	1,811	1.37	0.50	2.52	1,765	0.30	0.15	0.55	1,663	0.60	0.30	1.09
Burgiss	201	1.58	0.82	2.03												
B. Preqin performance summary statistics (equally weighted)																
PME	157	0.93	0.95	0.31	1,083	1.05	1.01	0.36	839	0.99	0.95	0.56	704	0.94	0.97	0.28
IRR	210	9.92	9.35	13.53	1,534	14.52	12.70	16.46	1,419	13.33	11.00	22.52	1,477	10.58	10.90	14.71
Multiple	315	1.34	1.26	0.49	1,811	1.56	1.44	0.65	1,765	1.74	1.38	2.66	1,663	1.36	1.32	0.51
C. Burgiss performance summary statistics (equally weighted)																
PME	201	0.89	0.91	0.31												
IRR	201	5.60	7.94	21.55												
Multiple	201	1.23	1.20	0.45												
D. Preqin performance summary statistics (value weighted)																
PME	157	0.93	0.96	0.23	1,083	1.06	1.04	0.30	839	1.02	0.99	0.42	704	0.93	0.98	0.29
IRR	210	9.68	9.70	10.85	1,534	13.82	12.90	11.72	1,419	12.26	11.00	16.45	1,477	9.41	10.90	12.66
Multiple	315	1.28	1.22	0.36	1,811	1.48	1.41	0.48	1,765	1.52	1.34	0.90	1,663	1.27	1.26	0.43

We compare the performance and cash flows of closed infrastructure funds with buyout, venture capital, and real estate funds. The sample includes funds raised in the period 2002–2018. Panel A reports summary statistics on *Fund size*, which is measured in $ bil. based on Preqin and Burgiss data. Panels B, C, and D summarize three performance measures on private funds: public market equivalent (PME) relative to the total return on the S&P 500 index, net IRR, and multiple of invested capital. We calculate the PME measure as the ratio of the sum of discounted distributions to the sum of discounted capital calls. The PME calculation uses cash flows until the end of 2019, which we downloaded from Preqin in June 2020. For each measure, we present the number of fund observations, mean, median, and standard deviation by fund type. Panel B presents equal-weighted performance measures for all fund types based on Preqin data. Panel C presents equal-weighted performance measures for infrastructure funds based on Burgiss data. Panel D presents value-weighted performance measures by fund size for all fund types based on Preqin data.

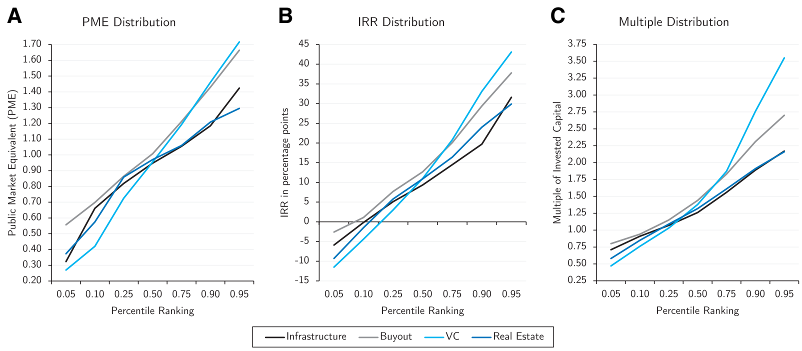

Figure 2
Fund type and performance distribution
This figure compares the distribution of performance delivered by infrastructure funds with the distribution of performance delivered by buyout, venture capital (VC), and real estate funds raised in the period 2002–2018. In panel A performance is measured using the public market equivalent (PME); in panel B performance is measured using the net internal rate of return (IRR); and in panel C performance is measured using the net multiple of invested capital. For each performance measure, we present the 5th, 10th, 25th, 50th, 75th, 90th, and 95th percentiles of the distribution.

deviations of performance measures available in Burgiss are similar to the statistics in Preqin.

In panel D of Table 3, we use fund size to estimate value-weighted performance measures, which better reflect the overall returns obtained by investors. For all alternative assets, it seems that fund size is negatively related to risk, as the standard deviations of value-weighted performance measures are lower than in panel B. The fund size-weighted performance measures for infrastructure funds remain relatively low compared to the other private funds, while the standard deviation remains high and close to the statistics for buyout and real estate funds.

In Figure 3, we extend the analysis on the payout policy of infrastructure funds by comparing their cash flows over time with the cash flows delivered by buyout, VC, and real estate funds. We use cash flow data from Preqin for funds with a 2002 vintage or later and focus on the annual amounts of capital calls and distributions. If closed infrastructure funds deliver more stable cash flows, as argued by the finance industry and expected by investors, their distributions would be expected to have persistent stable amounts over a longer horizon that match the long life span of the underlying assets. We standardize the cash flows over the life of a fund, so that time period $t=1$ corresponds to the vintage year of the fund, and we standardize the commitment amount to \$10 million. We present the timeline of cash flows for the first 16 years of the fund life, as most closed funds are fully divested by that time.

Based on panels A and C of Figure 3, the dollar amounts of capital calls and distributions over time provided by infrastructure funds are situated between the dollar amounts of capital calls and distributions delivered by buyout and

Table 4
Percentage exited deals and performance

	Reporting		PME		Net IRR		Multiple	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
%Exited deals	0.269**		0.636***		19.944***		0.561***	
	[0.113]		[0.206]		[3.779]		[0.191]	
%Exited deals in years 0-5		0.290*		0.851***		25.762***		0.787***
		[0.151]		[0.209]		[3.868]		[0.204]
%Exited deals in years 5-10		0.246*		0.140		9.088*		0.201
		[0.145]		[0.263]		[5.152]		[0.155]
%Exited deals in years >10		0.201		−0.822		−8.028		−0.041
		[0.372]		[1.315]		[8.749]		[0.342]
Fund size	0.167***	0.168***	−0.014	−0.027	−2.128*	−1.785	−0.056*	−0.050
	[0.026]	[0.026]	[0.022]	[0.025]	[1.076]	[1.039]	[0.032]	[0.031]
%Greenfield	0.115	0.114	0.143	0.093	−0.261	−0.583	−0.015	−0.039
	[0.092]	[0.092]	[0.091]	[0.071]	[4.434]	[4.119]	[0.121]	[0.111]
%Brownfield	0.052	0.052	0.134	0.137	−6.643	−8.309	0.003	−0.063
	[0.125]	[0.126]	[0.168]	[0.157]	[13.056]	[13.182]	[0.226]	[0.216]
%Concession	−0.138	−0.136	−0.295	−0.285*	−13.775	−12.880	0.101	0.107
	[0.134]	[0.130]	[0.185]	[0.157]	[13.509]	[13.445]	[0.133]	[0.122]
Vintage FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
%Deal region	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
%Deal industry	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	526	526	125	125	183	183	260	260
Adjusted R-squared			.445	.487	.168	.198	.359	.378

In this table, observations are at the infrastructure fund level. Columns 1 and 2 present results of logit regressions in which the dependent variable equals one if a closed infrastructure fund reports the net IRR, a multiple of invested capital, or cash flows in the Preqin database. We present the marginal effects (elasticities) at the means of the independent variables. In the other columns, we limit attention to infrastructure funds reporting performance. In columns 3 and 4 performance is measured using the public market equivalent (PME), in columns 5 and 6 performance is measured using the net internal rate of return (IRR), and in columns 7 and 8 performance is measured using the net multiple of invested capital. *%Exited deals* measures the percentage of exited deals from the total number of deals made by the fund. *%Exited deals in years 0-5*, *5-10*, and *>10* capture the percentage of exited deals in the first 5 years after the transaction date, in 5 to 10 years after the transaction, and in more than 10 years after the transaction date, respectively. *Fund size* is the natural logarithm of the assets raised by the infrastructure fund. *%Greenfield* and *%Brownfield* measure the percentage of fund investments in deals in greenfield and brownfield project stage, respectively (the omitted category is secondary stage). *%Concession* measures the percentage of deals when a fund enters a concession deal with the government. We include vintage year fixed effects and control for the percentage allocated to different infrastructure industries and geographical regions. We cluster standard errors by vintage year and report standard errors in brackets. $^{*}p<.1$; $^{**}p<.05$; $^{***}p<.01$.

real estate funds.[16] Infrastructure funds do not provide a different payout profile as their distributions are not more stable (flatter) over time and do not last for a longer period of time. The only significant difference between infrastructure and buyout funds is that buyout funds distribute higher amounts which corresponds

16 The similar timeline of capital calls by infrastructure funds and other private funds is important because Preqin-reported IRRs do not penalize funds for delaying capital calls or not calling the entire committed amount (Gupta and van Nieuwerburgh 2021). When there are gaps between called and committed capital, LPs may be constrained by the need to keep liquid assets on hand. For example, if infrastructure funds were to call capital more quickly than buyout funds do, and if there are in fact conceded returns to having to keep liquid assets in preparation for a capital call, then the Preqin-reported IRRs of buyout funds could be thought of as artificially high. The fact that Figure 3 shows infrastructure funds exhibiting on average a similar timeline of capital calls as other private funds to some extent alleviates this concern. Furthermore, in Internet Appendix Tables IA.7, IA.8, and IA.15, we show that our results are robust to three alternative calculations of the IRR that correct for delayed or lower capital calls. In our baseline results, we use Preqin-reported IRRs as they are available for a broader sample of infrastructure funds.

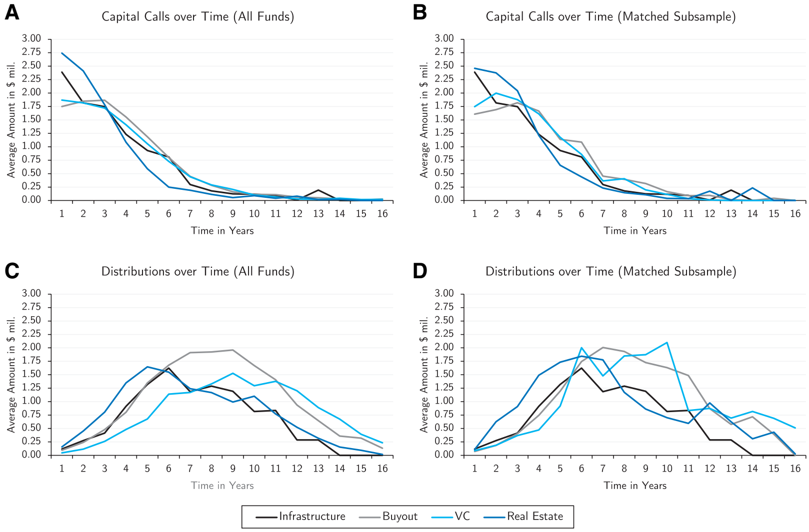

Figure 3
Comparison of the cashflows of infrastructure funds with other private funds
This figure presents the cash flows of infrastructure, buyout, venture capital (VC), and real estate funds raised in the period 2002–2018. We standardize the cash flows over time so that time period $t = 1$ corresponds to the vintage year of the fund. All cash flows are based on a $10 mil. initial commitment. We present the amounts of capital calls and distributions per year in $ mil. In panels A and C, we use the entire sample of buyout, VC, and real estate funds. In panels B and D, we use a matched subsample of buyout, VC, and real estate funds. We create this subsample by matching infrastructure funds with buyout, VC, and real estate funds based on three criteria: vintage year, geographical focus (North America, Europe, and Rest-of-World), and fund size (closest match).

to their better performance observed in Table 3. Compared to infrastructure funds, real estate funds seem both to call more capital earlier and to start distributing capital back to investors earlier, but the general lifecycle of these funds is similar. Even compared to VC funds, infrastructure funds have a similar timeline of capital calls but more distributions in the early years of the fund life.

Table 3 shows that the number of buyout, VC, and real estate funds raised since 2002 is significantly greater than the number of infrastructure funds raised during the same time period. One potential worry is that infrastructure funds differ in their focus from the other private funds, because they invest more outside of the United States, and are relatively larger. Panel A of Table 3 shows the differences in average fund size across the four types of private funds. Regarding the regional focus, only 55% of the infrastructure funds with cash flow data have a U.S. focus, while 65% of the buyout, 73% of the VC, and 75% of the real estate funds have a U.S. focus. Infrastructure funds may also have a somewhat different distribution of the vintage year in which they are raised. To address these concerns, in panels B and D of Figure 3, we replicate the analysis from panels A and C, but instead of using the entire sample of buyout, VC, and real estate funds, we use a matched subsample of these funds. We create this subsample by matching infrastructure funds with buyout, VC, and real estate funds based on three criteria: vintage year, geographical focus (North America, Europe, and Rest-of-World), and fund size (closest match). The results with the matched subsample confirm that infrastructure, buyout, and real estate funds have a similar profile of capital calls and distributions over time. Overall, despite the fact that infrastructure covers long-lived tangible assets in highly regulated industries, the business model of closed funds does not translate the differences in the underlying assets into a stable stream of distributions.

The main reason infrastructure funds have a similar payout profile to other private funds is that their performance and distributions are primarily driven by deal exits. The fraction of exited investments has been used as a proxy for performance in the private equity literature when analyzing the performance of buyout and VC funds (Hochberg, Ljungqvist, and Lu 2007; Sorensen 2007; Phalippou and Gottschalg 2009; Lopez-de-Silanes, Phalippou, and Gottschalg 2015). In Table 4, we show that the exit rates at the fund level are indeed related to performance, as they could in theory also capture differences in the investment horizon or other preferences.[17]

We investigate the relation between exit rates and reporting performance statistics, keeping in mind that the comparison between Preqin and Burgiss in Table 3 suggested that, if anything, Preqin may have an upward bias in performance reporting. Even relatively standard statistics on performance, such as IRRs and multiples, are available for only 273 of the 538 closed infrastructure funds we study. Columns 1 and 2 present the results of logit regressions in which the dependent variable equals one if a closed infrastructure fund reports the IRR, a multiple of invested capital, or cash flows (which allow for a PME calculation) in the Preqin database. We control for vintage year of the fund as well as the percentage allocated to projects in different industries, regions, project stages, and concessional backing. The vintage year indicators address the truncated distribution of deal exits as many recent funds do not report any return measures. In column 1, we find that a 10-percentage-point increase in the percentage of exited deals is associated with a 2.69-percentage-point higher probability of reporting performance, which further suggests that the standard performance measures may overestimate the performance of infrastructure funds, as such statistics may be underreported in cases in which funds are less likely to exit deals. We also observe that larger funds are more likely to report performance.

In columns 3 to 8, we find more direct evidence that exiting a deal proxies for better performance. Based on column 3, a 10-percentage-point increase in the percentage of exited deals is associated with an increase in the PME by 0.064. Based on columns 5 and 7, a 10-percentage-point increase in the percentage of exited deals is associated with a 1.99-percentage-point higher net IRR and an increase in the multiple of invested capital by 0.056. In columns 2, 4, 6, and 8,

[17] The number of funds in Table 4 with available performance data is slightly smaller in each of the panels than in Table 3 because the analysis requires information on underlying deals and on investors that committed capital.

we split the percentage of exited deals based on the holding period. We examine the relation between performance and the percentage of exited deals in the first 5 years after the transaction date, in 5 to 10 years after the transaction, and in more than 10 years after the transaction date. The positive relation between performance and exit rates is primarily driven by relatively quick exits within the first 5 years after the investment date and to a lesser extent by exits in the period from year 5 to year 10. Investments held for a period of longer than 10 years seem to be negatively related (or at least unrelated) to performance, even after controlling for the share of fund investments in different regions and industries.

The positive relation between quick exits and performance provides an explanation for why the cash flow profile of infrastructure funds does not differ from the cash flow profile of other private funds. Even though infrastructure funds hold tangible assets frequently backed by concession agreements, the performance and distributions delivered to investors by infrastructure funds seem to be primarily a reflection of asset sales and not of stable persistent dividend yield. While the positive relation between quick exits and net IRR could be mechanical, the other performance measures are more robust.[18] The multiple of invested capital actually rewards later exits because it does not take into account the time value of money, and the PME controls for the contemporaneous stock market performance. In line with previous findings in the private equity literature, closed infrastructure funds sell their better-performing assets earlier and keep their worse-performing assets until it is time to wind down the fund. The closed fund structure provides incentives to exit the best performing assets quickly, which is incompatible with the investor expectations of reliable incomes stream in the long run.

Even if infrastructure funds have a similar payout policy and a similar distribution of performance to other private funds, it could be the case that they exit investments and distribute cash in different parts of the business cycle. In Table 5, panel A, we assess the claim that infrastructure fund cash flows may be less sensitive to the business cycle and, thus, the possibility that infrastructure funds might still provide diversification and liquidity benefits relative to other private funds, despite our finding that their cash flow profiles are similar.

[18] Internet Appendix Tables IA.8 replicates columns 5 and 6 of Table 4 and shows that our results are robust to alternative calculations of the IRR performance measure that penalize funds for delaying capital calls or not calling the entire committed amount. We follow Gupta and van Nieuwerburgh (2021) and calculate the IRR in three alternative ways. First, the *IRR sum call* measure assumes that each fund makes only one capital call equal to the undiscounted sum of all calls. Second, for several older infrastructure funds, the sum of all calls is greater than the amount of committed capital as sometimes partnership provisions allow GPs to reinvest distributions from early exits into new investments. The *IRR sum call max cap $10* measure also assumes that each fund makes only one capital call equal to the undiscounted sum of all calls, but truncates the capital call amount above $10 million (the standardized amount of committed capital). Third, GPs do not always call the full committed amount because they may lack profitable investment opportunities, engage in market timing, or try to optimize the number of simultaneously managed deals. The *IRR $10 call residual in Treasury bills* measure assumes that the LP gives $10 million to the GP on the first call date, and any committed amount that has never been called is invested in Treasury bills and returned to the LP at the end of the life of the fund (we combine it with the last cash flow in our calculation).

Table 5
Cash flows and business cycle

A. Infrastructure cash flows and business cycle

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
ln(Yield spread)	0.342	0.320	0.722	0.550	−0.076*	−0.076*	−0.074*	−0.066*
	[0.213]	[0.219]	[0.881]	[0.813]	[0.043]	[0.043]	[0.039]	[0.038]
ln(P/D)	4.981***	4.098**			1.177***	1.140***	0.224	0.584
	[1.855]	[1.979]			[0.365]	[0.354]	[0.376]	[0.402]
Inflation		0.161				0.007		−0.065**
		[0.139]				[0.025]		[0.028]
CFNAI MA3			1.037*					
			[0.521]					
CFNAI production & income				1.530**				
				[0.734]				
Fund age FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Quarter FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Fund focus FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	3,066	3,066	3,066	3,066	3,066	3,066	3,066	3,066
Adjusted *R*-squared	.128	.128	.127	.127				
Pseudo-*R*-squared					.057	.057	.090	.090

B. Diversification within fund-age and across fund-types

	Baseline buyout & buyout	Buyout & infra	Buyout & VC	Buyout & RE	Baseline VC & VC	VC & infra	VC & buyout	VC & RE
SD baseline all funds	4.825	4.984	4.752	4.897	5.867	5.962	5.837	5.951
SD baseline funds above median	5.184	5.443	5.107	5.346	6.425	6.591	6.400	6.566
SD baseline funds above 75^{th} perc.	5.631	5.941	5.536	5.864	7.491	7.764	7.378	7.806

In panel A, we examine the relation between cash flows of infrastructure funds and market conditions. The unit of observation is by fund-quarter. *ln(P/D)* is the natural logarithm of the price/dividend ratio of the S&P 500. *ln(Yield spread)* is the natural logarithm of the Moody's Baa-Aaa yield spread. We orthogonalize *ln(Yield spread)* with respect to *ln(P/D)*. *Inflation* is the U.S. CPI for all urban consumers. *CFNAI MA3* is the 3-month moving average of the Chicago Fed National Activity index. The *CFNAI Production & Income* category of this index measures industrial production, manufacturing, construction, and real income. All variables are lagged and measured at the end of the previous quarter. In columns 1 to 4, we estimate OLS regressions and the dependent variable is net cash flows (distributions – capital calls) as a percentage of committed capital. In columns 5 and 6, we present tobit regression results where the dependent variable is the natural logarithm of the distributions as a percentage of committed capital plus one. In columns 7 and 8, we present tobit regression results where the dependent variable is the natural logarithm of the capital calls as a percentage of committed capital plus one. All regressions include fund age fixed effects measured in quarters, calendar quarter fixed effects, and fund focus fixed effects. We cluster standard errors on a year-quarter level and report standard errors in brackets. Panel B examines how cash flow volatility is affected by including infrastructure funds in a portfolio of buyout or VC funds. At each point in time, the methodology collapses the cross-section of funds raised in a given vintage-quarter by taking the average of the fund-level net cash flows. The methodology then calculates the time-series standard deviation of each of these diversified vintage-quarter investments. The average across quarters of the time-series standard deviation of the diversified vintage-quarter investments represents the average volatility an institutional investor would experience by investing in one of the vintage-quarter portfolios. Next, we match infrastructure funds with buyout, VC, and real estate funds based on three criteria: vintage year, geographical focus, and fund size (closest match). To examine how cash flow volatility is affected by including different fund types in the portfolio, we replace the matched buyout funds with the matched infrastructure, VC, or real estate (RE) funds. Our first baseline portfolio includes either all unmatched buyout or VC funds. The other baseline portfolios limit the sample to only buyout or VC funds above or equal to the median fund size in any given vintage-quarter, and then also above or equal to the 75^{th} percentile fund size in any given vintage-quarter, when constructing the aggregated vintage-quarter investments. $*p<.1$; $**p<.05$; $***p<.01$.

Robinson and Sensoy (2016) find that the cash flows of private equity funds are procyclical. We follow their approach and analyze the cyclicality of cash flows provided by infrastructure funds. Similar to Robinson and Sensoy (2016), we focus on two variables that capture the business cycle. *Ln(P/D)* is the natural logarithm of the price-dividend ratio of the S&P 500 index, based on data from Robert Shiller's website. *Ln(Yield Spread)* is the natural logarithm of the Moody's Baa-Aaa yield spread, using data from the FRED database of Federal Reserve Bank of St. Louis. Following Robinson and Sensoy (2016), we orthogonalize *ln(Yield Spread)* with respect to *ln(P/D)*. We extend the analysis by examining the inflation hedging potential of cash flows from infrastructure funds. *Inflation* is the U.S. CPI for all urban consumers from the Bureau of Labor Statistics. All variables are lagged and measured at the end of the previous quarter.

Table 5, panel A, presents the results from the analysis on a fund-calendar quarter level. In columns 1 to 4, we estimate ordinary least squares (OLS) regressions, where the dependent variable is net cash flows (distributions minus capital calls) as a percentage of committed capital. In columns 5 to 8, we estimate Tobit regressions in which the dependent variable is either the natural logarithm of the distributions as a percentage of committed capital or the natural logarithm of the capital calls as a percentage of committed capital. All regressions include fund age fixed effects measured in quarters. The fund-age fixed effects control for the predictable timeline of cash flows that arises from the life cycle of private funds and for the negative mechanical relation between fund age and market conditions as more young funds are raised when the business conditions are favorable. The regressions include indicators for fund focus (the United States, Europe, Rest-of-World/Global) because most of the private funds reporting cash flows data in Preqin are based in the United States, but their investment focus can differ. We also include calendar quarter fixed effects because we observe significant cyclicality in the cash flows.

The net cash flows of infrastructure funds seem procyclical as they are positively related to the price/dividend ratio. Based on column 1, a 10% increase in the price-dividend ratio is associated with a 0.498 ($=4.981\times \ln(1.1)$) percentage point increase in net cash flows of infrastructure funds. Columns 5 and 6 show that the procyclicality of cash flows delivered by infrastructure funds is primarily a consequence of the procyclicality of their distributions. The capital calls are not sensitive to the price-dividend ratio, but do respond to changes in the yield spread, which captures debt market conditions and affects the financing of investments. Internet Appendix Tables IA.9 confirms the findings of Robinson and Sensoy (2016) that the net cash flows of buyout, VC and real estate funds are procyclical due to higher sensitivity of their distributions to the business cycle. We conclude that institutional investors will receive cash flows from their infrastructure fund investments at times in the business cycle that are very similar to the times when their other investments in private markets distribute cash flows, and also when their investments in public equity markets perform well. The cash flow distributions of infrastructure funds do not diversify the overall exposure that institutional investors face across the business cycle.

Regarding the inflation hedging properties of infrastructure cash flows, if infrastructure delivers inflation protection, we would expect to observe a positive relation between the net cash flows and realized inflation in column 2, which should be driven by a positive relation with distributions in column 6. We do not find a significant positive relation between infrastructure cash flows and realized inflation during our sample period. However, our sample does not cover periods of high inflation and the number of deals located in countries with high inflation is also low. Thus, while we do not find evidence that infrastructure has inflation hedging properties during our sample period, our analysis does not cover a sample when the inflation hedging potential of infrastructure would be valuable, so that it is still possible that cash flows might respond more to larger swings in the inflation rate.

In columns 3 and 4, we also analyze the relation between infrastructure cash flows and the Chicago Fed National Activity index (CFNAI). According to the Chicago Fed (2020), "CFNAI often provides early indications of business cycle turning points and changes in inflationary pressure." Therefore, we replace the *ln(P/D)* and *Inflation* in the regression model and include the CFNAI three-month moving average. We observe a positive relation between the net cash flows of infrastructure funds and the CFNAI three-month moving average, confirming our conclusion that infrastructure funds deliver higher net cash flows during periods of economic expansion. The CFNAI consists of four components and the positive relation is driven by the production and income category, which encompasses 23 data series that measure industrial production, manufacturing, construction, and real income. The positive relation with the production and income category confirms that the cash flows delivered by infrastructure funds are highly sensitive to the business cycle because this category tends to turn negative more quickly during a recession and turn positive once a recovery begins (Chicago Fed 2020). The other categories, such as unemployment, personal consumption, and housing, do not respond quickly to changes in the business cycle, and infrastructure cash flows do not seem to be related to these components of CFNAI measure.

The cyclicality on a fund level might in theory not affect an institutional investor that holds a portfolio of infrastructure funds. For an institutional investor that can commit capital to multiple funds over time, it is possible that the distributions would match the capital calls and reduce the cyclicality of cash flows, especially if good times lead to more distributions from existing funds at the same time as more commitments to new funds. However, the estimations in Internet Appendix Tables IA.10 on an investor-quarter level suggest that holding a portfolio of infrastructure funds does not enable institutional investors to markedly reduce cyclicality relative to cash flows at the fund level, primarily because of the procyclicality of distributions. The coefficients for the P/D ratio, yield spread, and CFNAI have similar economic magnitudes to the coefficients for these variables in Table 5. Our results are in line with the conclusions of Brown et al. (2021) regarding the inability of institutional investors to time their exposure to private equity. In addition, even if the portfolio composition and exposure remain constant over time, the quick turnover of the underlying assets exposes institutional investors to higher fees. Closed funds charge carried interest above a certain hurdle rate as well as transaction fees for each deal. Institutional investors will have to pay these fees even if they are exposed to the same portfolio of underlying assets over time.

Even though the cash flows of infrastructure funds are procyclical, these funds could still be beneficial for portfolio diversification if including them reduces idiosyncratic risk. In Table 5, panel B, we adapt the methodology from Robinson and Sensoy (2016) and examine how cash flow volatility is affected by including infrastructure funds in a portfolio of buyout or VC funds. The methodology examines the effects of diversifying across funds of a given age within the same fund type. The first step collapses the cross-section of funds raised in a given vintage-quarter by taking the average of the fund-level net cash flows, scaled by committed capital. This step generates 117 vintage-quarter investments, representing a diversified portfolio of buyout/VC funds raised in a given quarter. The second step calculates the time-series standard deviation of the cash flows of each of these 117 diversified vintage-quarter investments. Finally, the average across quarters of the time-series standard deviation of the diversified vintage-quarter investments represents the average volatility an institutional investor would experience by investing in one of the vintage-quarter portfolios.

We extend this analysis by examining the role of diversification across fund types, in addition to diversification across funds with the same age. We match infrastructure funds with buyout, VC, and real estate funds based on three criteria: vintage year, geographical focus (North America, Europe, and Rest-of-World), and fund size (closest match). To examine how the cash flow volatility is affected by including different fund types in the portfolio, we replace the matched buyout funds with the matched infrastructure, VC, and real estate funds. Thus, the benchmark portfolio invests only in buyout funds and diversifies only within fund age, while the alternative portfolios invest in all unmatched buyout funds and the matched funds from other types. The alternative portfolios diversify across fund type and within fund age.

Our baseline portfolio includes either all unmatched buyout or all unmatched VC funds. However, we recognize that there are many more buyout and VC funds than infrastructure funds and that large institutional investors might have minimum commitment levels and may not consider smaller funds. We therefore consider the possibility that adding infrastructure to a smaller portfolio of buyout or VC funds might have diversification benefits. To do this, we limit the baseline portfolio to only buyout or VC funds above or equal to the median fund size in any given vintage-quarter, and then also above or equal to the

75th percentile fund size in any given vintage-quarter, when constructing the aggregated vintage-quarter investments. Larger buyout and VC funds raise capital from many institutional investors and are more relevant for their portfolio composition.

The conclusion from this analysis is that infrastructure provides very few diversification benefits. All private funds have net cash flows that are sensitive to the business cycle. Diversifying across fund types has only a marginal impact on the volatility of the net cash flows of a portfolio of private funds. Increasing the number of funds matters of course for reducing idiosyncratic volatility, but there is no additional benefit that we can detect that comes from diversifying across fund types into infrastructure. For instance, as shown in Table 5, panel B, the volatility of cash flows averages 4.825% when investing only in buyout funds, and it even increases to 4.984% when replacing the matched buyout funds with infrastructure funds. The only marginal improvement to a buyout fund portfolio appears to be the addition of VC funds (and vice-versa).

The above analysis suggests that infrastructure is sensitive to the market conditions and moves together with other private funds, but it does not directly examine the risk-adjusted performance of the infrastructure asset class. In Table 6, we implement the stochastic discount factor (SDF) valuation method of Korteweg and Nagel (2016) to estimate the generalized public market equivalent (GPME) of infrastructure funds. The GPME estimates a risk-adjusted PME performance measure by accounting for the payout delivered by private funds and contemporaneous risk factor realizations. We focus on two benchmark factor portfolios that invest in the S&P 500 stock market index and Treasury bills.

The unit of observation in Table 6 is again a fund-calendar quarter. For funds that are not yet liquidated by the end of our sample period, we follow the approach of Korteweg and Nagel (2016) and calculate performance using the self-reported net asset value (NAV) at the end of the sample period as a proxy for a final distribution. In panel A, we examine funds raised in the 2002–2018 period which encompasses a broader sample of infrastructure funds. However, one concern is that some of these funds have been raised recently and they still have not called all capital commitments or distributed larger amounts of capital. Therefore, in panel B, we limit our attention to more mature funds raised in the 2002–2013 period, since the distributions of more recent funds will be based almost entirely on NAVs and these estimations could deviate from the true value of their underlying assets (Brown, Gredil, and Kaplan 2019). Funds raised in the 2002–2013 period have already called almost the entire committed capital and have distributed back significant amounts of capital (some of them are liquidated).

The GPME estimation gives each fund equal weight, since we normalize the cash flows for a total commitment of $1 (Korteweg and Nagel 2016). Another potential concern is that the estimations are driven by smaller funds that do not raise large amount of capital from a broader pool of LPs. We address this

Table 6
Generalized public market equivalent

	All funds		Size ≥ $250 mil.		Size ≥ $500 mil.	
	(1)	(2)	(3)	(4)	(5)	(6)
A. Funds raised in 2002–2018						
GPME	−0.067**	−0.257**	−0.069**	−0.195	−0.095***	−0.284***
	(.013)	(.015)	(.013)	(.208)	(.001)	(.004)
a	0	0.111	0	0.111	0	0.096
		[0.032]		[0.035]		[0.034]
b	1	6.269	1	6.168	1	5.749
		[1.099]		[1.156]		[1.188]
Funds	145	145	121	121	100	100
B. Funds raised in 2002–2013						
GPME	−0.100**	−0.338***	−0.091**	−0.302**	−0.138***	−0.383***
	(.014)	(.006)	(.038)	(.031)	(.001)	(.000)
a	0	0.079	0	0.076	0	0.063
		[0.025]		[0.026]		[0.025]
b	1	5.109	1	4.999	1	4.577
		[0.903]		[0.956]		[0.974]
Funds	67	67	56	56	47	47

In this table, we use the stochastic discount factor (SDF) valuation method of Korteweg and Nagel (2016) to estimate the generalized public market equivalent (GPME). The unit of observation is infrastructure fund cash flows on a quarterly frequency. The quarterly cash flows are normalized by fund size to a total commitment of $1, and they are calculated as the difference between distributions and capital calls, rather than their ratio (so a PME equal to one in Table 3 corresponds to a GPME equal to zero in this table). In panel A, we analyze the cash flows of funds raised in the 2002-2018 period, while in panel B, we analyze the cash flows funds raised in the 2002-2013 period. We estimate the GPME for all infrastructure funds in columns 1 and 2, as well as separately for infrastructure funds with fund size above $250 mil. in columns 3 and 4, and for infrastructure funds with fund size above $500 mil. in columns 5 and 6. Columns 1, 3, and 5 with $a=0$ and $b=1$ correspond to the public market equivalent calculation of Kaplan and Schoar (2005). In columns 2, 4, and 6, a and b are SDF parameters that correctly price benchmark funds that receive the same inflows as the private funds but that invest in the S&P 500 index and Treasury bills. We report standard errors of the SDF parameter estimates in brackets, and p-values of the J-test of $GPME=0$ in parentheses.

concern by estimating the GPME separately for infrastructure funds with fund size above $250 million in columns 3 and 4, and for funds with fund size above $500 million in columns 5 and 6.

The results in columns 1, 3, and 5 of Table 6 restrict the SDF parameters to take values $a=0$ and $b=1$ and under this constraint correspond to the PME of Kaplan and Sensoy (2015). However, the GPMEs are calculated as the difference between discounted distributions and capital calls instead of ratios, so a PME equal to one in Table 3 corresponds to a GPME equal to zero in Table 6. The estimations in these columns prevent the SDF from adjusting for market risk exposure (Korteweg and Nagel 2016). In columns 2, 4, and 6 of Table 6, a and b are SDF parameters that price benchmark funds which receive the same in inflows as the private funds but invest in both the S&P 500 index and Treasury bills instead of private deals.

Based on column 1, infrastructure delivers a negative and significant PME of −0.067, which is very close to the PME of 0.93 reported in Table 3.[19]

[19] The sample in Table 6 includes funds that have called at least 25% of their committed capital, while the sample in Table 3 is slightly broader as we do not impose any constrains when calculating the summary statistics.

Column 2 relaxes the equity premium and risk-free rate restrictions implicit in the PME and shows that infrastructure delivers an even lower GPME of −0.257. This means that relative to investing in the S&P 500 and Treasury bills, a $1 commitment to infrastructure led to a risk-adjusted loss of $0.257 over a fund's lifetime in present value terms (Korteweg 2019). The difference of 19 cents per dollar of commitment to infrastructure fund arises because the b parameter of the SDF takes a value of 6.269, which means that the PME understates the public market equity premium and implies that on average infrastructure funds have a market beta above one.

When comparing the results across the subsamples with different limits on the minimum fund size, the main conclusion is that the negative risk-adjusted performance of infrastructure funds is significant among larger funds that raise large commitments from many LPs. Thus, the GPME estimates are not driven by small funds and we can extend the main conclusions from this analysis to the entire infrastructure asset class. Based on panel B, we also conclude that older funds with more robust cash flows series have lower PME and GPME estimates. This panel suggests that the negative risk-adjusted performance of infrastructure funds is not driven by young funds and NAV estimates.

In Internet Appendix Tables IA.11, we estimate the GPME for buyout, VC, and real estate funds, and find that other private funds have a negative risk-adjusted performance, generally in line with Korteweg and Nagel (2016) and Gupta and van Nieuwerburgh (2021). While the riskiness of other private equity funds is not surprising, the similarity of infrastructure risk-return properties contradicts investor expectations and preferential regulatory treatment. If infrastructure delivered stable and less-risky performance, we would expect to find a higher GPME than PME, similar to the result for mezzanine funds obtained by Korteweg and Nagel (2016). If infrastructure funds have a beta of less than one, the PME will understate rather than overstate the (abnormal) performance of infrastructure funds. These findings suggest that closed infrastructure funds do not meet investor expectations of stable returns and should be evaluated in a similar way as other private market funds investing in equity assets.

One potential reason the risk of infrastructure investments is high, even though they provide exposure to tangible assets that are often backed by stable concessions, is that infrastructure deals are typically financed with a high degree of leverage. For a subsample of 683 transactions, Preqin provides data on the proportion of deal financed by equity and debt and we can calculate the leverage ratio as of the time of the deal. Internet Appendix Tables IA.12 shows that the median infrastructure transaction is financed by 66% debt and 34% equity. The median leverage ratio for social infrastructure is the highest and equals 88%. Social infrastructure is the industry with the highest proportion of concession agreements backing the deals, so the potential stability of cash flows seems to be used to increase the amount of leverage.

Overall, the typical profile of cash flows over time provided by infrastructure funds does not differ from the payout profile offered by more established alternative assets, like buyout, VC, and real estate. Based on the distribution of returns and payout profiles, we conclude that it would be difficult for closed infrastructure funds to meet investor expectations for stable long-term cash flows. Based on the relation between their cash flows and the business cycle, we also conclude that it would be difficult for infrastructure funds to diversify liquidity exposures and sensitivity to market swings relative to other private funds. Moreover, the GPME performance measure suggests that infrastructure funds also underperform public markets on a risk-adjusted basis.

3. Performance Differences between Public and Private Investors

In this section, we move the analysis from an asset class level to an investor level and study the investor experience in infrastructure. Even though closed infrastructure funds have failed to deliver attractive risk-return properties and meet investor expectations, they have experienced a steady increase in AUM over the past decade. To measure the total value of assets in closed funds over this period, we combine information on the ratio of residual value to paid-in capital, the percentage of capital called, and fund size. As shown in the lower bars of Figure 4, we estimate that over the past 10 years, the amount of AUM by infrastructure funds with performance reported in Preqin increased from $23 billion in 2008 to $282 billion in 2019.

On the one hand, this estimate could overstate the AUM if infrastructure funds overestimate the value of their unrealized assets (Phalippou and Gottschalg 2009). On the other hand, one way in which this estimate significantly understates AUM is that it considers only the assets managed by funds that report performance in the Preqin database. We attempt to remedy this by making additional imputations in the upper bars of Figure 4. Specifically, we assume that every fund that does not report performance holds 25% of the average assets of reporting funds from the same vintage, yielding $204 billion in unrealized value in nonreporting funds and a total of $486 billion in total unrealized value across all funds in 2019. We note that this total does not include the assets held by listed and open-ended funds, nor does it include the infrastructure assets directly held by institutional investors.

This rising trend in infrastructure AUM is surprising given the track record that we have documented in Section 2. Private equity and hedge funds grew as asset classes after very successful years driven by increased allocations from university endowments, foundations, and family offices in the early years (see, e.g., Dichev and Yu 2011; Sensoy, Wang, and Weisbach 2014; Ivashina and Lerner 2019). We document that the growth of infrastructure is driven by increased allocations from public investors over time. Figure 4 presents the percentage of investor-deal observations by investor type and transaction year of completed deals. Private investors accounted for a larger share of

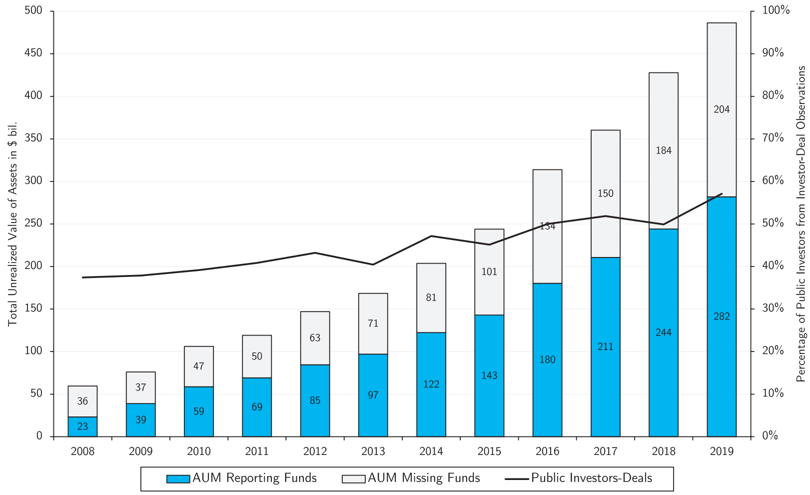

Figure 4
Assets under management and percentage of public investors
In this figure, we rely on the reported unrealized value of assets to estimate the amount of assets under management (AUM) in $ bil. by closed infrastructure funds. Specifically, we download the time-series of annual performance snapshots for the time period 2008-2019 from Preqin and use the ratio of residual value to paid-in capital to estimate the time series of AUM. We transform the ratio of residual value to paid-in capital to dollar amounts using the percentage of capital called and fund size. The lower bars of this figure show the amount of AUM by infrastructure funds that report performance in Preqin. Since this estimate could significantly understate the AUM, as it limits the sample to funds reporting performances in Preqin, the upper bars were added as imputations for the AUM for closed funds that do not report performance. We assume that every fund that does not report performance holds 25% of the average assets of reporting funds from the same vintage year. The right axis measures the relative importance of public and private institutional investors over time and shows the percentage of investor-deal observations completed by public investors in the 2008-2019 period.

the infrastructure deals and fund commitments in the past, but their share is declining over time. Public investors have increased their share from 37% of investor-deal observations in 2008 to 57% in 2019.

The increasing trend in infrastructure AUM presented in Figure 4 is likely to continue in the coming years as many (public) investors are targeting higher allocation weights to infrastructure than their current actual asset allocation. For example, in 2019, the Employees Retirement System of Texas (2019) reported in their annual report a target allocation of 7%, compared to an actual allocation of 2.9% ($0.8 billion fair value of investments and $0.9 billion unfunded commitments that have been made but still need to be called by GPs). Looking at sovereign wealth funds, the Norwegian Government Pension Fund Global received an approval from the government in 2019 to start investing up to 2% (around $20 billion) of the fund's value in unlisted renewable energy infrastructure (Norwegian Ministry of Finance 2019).

In Table 7, we examine whether the expected social externalities of infrastructure funds drive public pension investments. To do so, we explore whether ESG preferences or regulation influence the number of investments of public institutional investors. First, we use the list of institutional investors that

Table 7
Number of infrastructure investments

	Number of investments				ln(Number of investments + 1)			
	1990-2020		2011-2020		1990-2020		2011-2020	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Public investor	0.124***	0.072***	0.311***	0.203***	0.055***	0.038***	0.133***	0.109***
	[0.016]	[0.011]	[0.038]	[0.032]	[0.006]	[0.005]	[0.013]	[0.013]
UN PRI signatory	0.385***	0.038	0.343***	0.045	0.138***	0.031*	0.121***	0.038**
	[0.086]	[0.037]	[0.083]	[0.045]	[0.025]	[0.018]	[0.024]	[0.019]
Mandatory regulation	0.151*	0.057	0.308*	0.204**	0.035*	0.026	0.077**	0.085***
	[0.083]	[0.037]	[0.158]	[0.093]	[0.019]	[0.016]	[0.033]	[0.029]
Voluntary regulation	0.014	−0.007	0.093	0.074	0.011	−0.002	0.046**	0.039**
	[0.026]	[0.019]	[0.063]	[0.067]	[0.011]	[0.009]	[0.019]	[0.020]
Public investor × UN PRI signatory		0.759***		0.692***		0.240***		0.198***
		[0.178]		[0.191]		[0.051]		[0.052]
Public investor × Mandatory regulation		0.162		0.127		−0.004		−0.052
		[0.183]		[0.240]		[0.043]		[0.053]
Public investor × Voluntary regulation		0.092*		0.065		0.047**		0.019
		[0.054]		[0.086]		[0.021]		[0.030]
log investor size	0.037***	0.036***	0.074***	0.073***	0.017***	0.017***	0.032***	0.032***
	[0.004]	[0.004]	[0.009]	[0.009]	[0.001]	[0.001]	[0.003]	[0.003]
Year of first investment	−0.010***	−0.009***	−0.009***	−0.008***	−0.005***	−0.005***	−0.002***	−0.002***
	[0.001]	[0.001]	[0.002]	[0.002]	[0.000]	[0.000]	[0.001]	[0.001]
LP country FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Vintage FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	57,691	57,691	18,610	18,610	57,691	57,691	18,610	18,610
Adjusted *R*-squared	.091	.103	.087	.097	.136	.144	.128	.135

This table analyzes the number of infrastructure investments per year by institutional investors. Observations are at the investor-vintage year level. If an institutional investor did not make any investments in a certain year, we replace the observation with zero. In columns 1 to 4, the dependent variable is the number of investments in infrastructure funds by investor-vintage year. In columns 5 to 8, the dependent variable is the natural logarithm of the number of investments plus one. We analyze the number of investments per year separately over the entire sample 1990-2020 and over the 2011-2020 period. *Public investor* is an indicator variable for institutional investors from the public sector. *UN PRI signatory* is an indicator variable for investors that have signed the UN principles for responsible investing. It varies by investor-year and equals to one in the year of the signing date and in the following period. *Mandatory regulation* and *Voluntary regulation* are indicator variables measuring whether an institutional investor faces mandatory or voluntary regulation to consider ESG factors in the investment decisions. The regulation variables also vary by investor-year, and they equal to one in the years after the mandatory or voluntary regulatory policy is enacted and zero otherwise. Estimations in columns 2, 4, 6 and 8 include also interaction terms between public investors and *UN PRI signatory*, *Mandatory regulation*, and *Voluntary regulation*. We control for the natural logarithm of investors' size (AUM) and year of first infrastructure investment. All estimations include vintage year fixed effects and investor (LP) country fixed effects. We cluster standard errors by institutional investor and report standard errors in brackets. $*p<.1$; $**p<.05$; $***p<.01$.

have signed the United Nations Principles for Responsible Investment (UN PRI) as a proxy for investors that have stronger preferences for investments with nonfinancial objectives. *UN PRI signatory* is an indicator variable for investors that have signed the UN PRI. It varies by investor-year and equals one in the year of the signing date and in the following period. Second, we use the UN PRI regulation database to create a list of institutional investors that are subject to ESG regulation. We distinguish between investors that face mandatory regulations that require them to consider ESG factors in their investment decisions, and investors that operate under voluntary regulations, such as suggested standards of good practice or ESG recommendations. The regulation variables also vary by investor-year; they equal one in the years after the mandatory or voluntary regulatory policy is enacted and zero otherwise.

The unit of observation in Table 7 is the investor-vintage year level. We create a balanced panel for all 1,861 institutional investors in our sample. If an institutional investor did not make any investments in a certain year, we replace the observation with zero. The dependent variable is either the number of investments in infrastructure funds (left panel) or the natural logarithm of one plus the number of investments (right panel). All specifications include vintage year fixed effects which capture the average number of investments in every vintage year. In columns 1 and 5, we find that public investors make relatively more investments than private investors, controlling for investor size, country, and experience. Columns 3 and 7 show that the higher amount of investments made by public institutional investors is driven by their increased allocations in the most recent decade (2011–2020), when public investors made 0.31 more investments per year in infrastructure than private investors. We do not report the results, but in the previous decades (1990–2010) the difference between public and private investors is not significant.

Investors with stronger ESG preferences, as proxied by the UN PRI, make also relatively more investments. However, the interaction term of public investors and the UN PRI signatories shows that public institutional investors in particular manifest their ESG preferences by an increased allocation to infrastructure. Based on column 2, public investors that have signed the UN PRI make 0.76 more infrastructure investments per year as compared to investors that have not signed the UN PRI.

Institutional investors also respond to ESG regulation by increasing their allocation to infrastructure. Mandatory regulation requiring investors to consider ESG factors has a similar impact on the number of investments made by public and private institutional investors as the interaction term with public investors is not significant. However, public investors seem to (proactively) increase more the number of their infrastructure investments in response to voluntary ESG regulation, as the interaction terms with public investors are significant in columns 2 and 6.

Overall, controlling for UN PRI signatories, mandatory regulation, and voluntary regulation explains a substantial amount of the higher number of infrastructure investments made by public investors over time. The coefficient for public investors declines from 0.124 in column 1 to 0.072 in column 2 when we add the interaction terms to the linear count specification, and from 0.055 in column 5 to 0.038 in column 6 to the log count specification. We conclude from this analysis that ESG factors, such as ESG regulations and adhering to the UN PRI, explain 25%–40% of the higher number of infrastructure investments made by public investors. The effect of social externalities on infrastructure investments is likely to continue in the coming years as the number of investors supporting the UN PRI (or similar initiatives) is increasing, and many current regulatory initiatives are extending the duties of institutional investors in sustainable investment and specifically climate change. For example, the European Union Regulation 2019/2088 on sustainability-related disclosures in the financial sector will become effective in 2021, the Illinois Sustainable Investing Act HB 2460 became effective in 2020, and many other countries and U.S. states are in the process of adopting ESG legislation.

While our main contribution is to provide evidence for the social externality channel that applies broadly to all institutional investors, additional channels are likely at work for specific public pension funds. Public pension funds face an accounting regulatory incentive to justify high discount rates for pension liabilities with high expected returns on pension assets (Novy-Marx and Rauh 2011, Andonov, Bauer, and Cremers 2017; Lu et al. 2019). Public pension funds therefore have the greatest incentive to adopt the view that infrastructure will provide higher returns than fixed income at lower risk than other alternative asset classes, while also diversifying their portfolio. Public pension funds would also most likely find the idea of long-duration, stable cash flows most appealing, given the nature of public pension liabilities, and might use infrastructure in the context of reaching for yield. These channels do not apply to all public investors, however, as sovereign wealth funds and government agencies do not have a liability side to their balance sheets.[20]

How do public investors perform in their infrastructure fund investments relative to private investors? In Table 8, we analyze the performance on an investor-fund level using PME, net IRR, and multiple of invested capital as performance measures. The advantage of this analysis is that we can directly include return measures as dependent variables. The disadvantage is that we can analyze only the performance of investments through closed funds (i.e., not through listed funds, open-ended funds, and direct deals), and the number of underlying closed funds is limited to the funds that report performance.[21] We double-cluster standard errors by institutional investor and infrastructure

[20] An incentive to smooth volatility may apply to institutional investors more broadly, as their spending and long-term payout commitments may still depend on the reported AUM, but this could well apply to private institutions, such as endowments and private pension funds, as well as to public institutions.

[21] One potential concern is that Preqin's process for obtaining performance data may lead to better coverage of the performance of funds with more public LPs, and in particular that underperforming funds selected by private investors will be particularly unlikely to report performance. In Table 10 and in Internet Appendix Tables IA.16,

Table 8
Investor type and performance

	PME		Net IRR		Multiple	
	(1)	(2)	(3)	(4)	(5)	(6)
Public investor	−0.026**		−1.810***		−0.038***	
	[0.012]		[0.588]		[0.014]	
U.S. public pension fund		−0.026*		−1.978**		−0.024
		[0.016]		[0.962]		[0.021]
Non-U.S. public pension fund		−0.024		−1.489*		−0.050**
		[0.019]		[0.764]		[0.020]
Government agency		−0.001		−1.057		−0.082
		[0.035]		[1.491]		[0.052]
Sovereign wealth fund		−0.069**		−4.196**		−0.052
		[0.028]		[2.022]		[0.039]
log investor size	0.006**	0.006**	−0.018	0.010	−0.001	−0.001
	[0.003]	[0.002]	[0.117]	[0.112]	[0.004]	[0.004]
Year of first investment	−0.001*	−0.001	−0.044	−0.031	−0.001	−0.001
	[0.001]	[0.001]	[0.033]	[0.040]	[0.001]	[0.001]
#Funds	−0.000	−0.000	−0.005	−0.003	0.000	0.000
	[0.001]	[0.001]	[0.026]	[0.025]	[0.001]	[0.001]
Fund type	Yes	Yes	Yes	Yes	Yes	Yes
LP country FE	Yes	Yes	Yes	Yes	Yes	Yes
Vintage FE	Yes	Yes	Yes	Yes	Yes	Yes
%Deal region	Yes	Yes	Yes	Yes	Yes	Yes
%Deal industry	Yes	Yes	Yes	Yes	Yes	Yes
%Project stage	Yes	Yes	Yes	Yes	Yes	Yes
%Concession	Yes	Yes	Yes	Yes	Yes	Yes
Observations	2,342	2,342	3,021	3,021	3,853	3,853
Adjusted R-squared	.450	.450	.150	.150	.326	.326

This table presents results of regressions in which the dependent variable is the performance of investors in closed infrastructure funds. Observations are at the investor-fund level. In columns 1 and 2 performance is measured using the public market equivalent (PME), in columns 3 and 4 using the net internal rate of return (IRR), and in columns 5 and 6 using the net multiple of invested capital. *Public investor* is an indicator variable for institutional investors from the public sector. We also split the public investors by type and include separate indicator variables for U.S. public pension funds, non-U.S. public pension funds, government agencies, and sovereign wealth funds. We control for the natural logarithm of investors' size (AUM) and year of first infrastructure investment. *#Funds* measures the number of investments in infrastructure funds by investor. We include two indicator variables for infrastructure funds that do not take only equity positions in infrastructure deals, but that also act as a fund-of-funds or debt fund. We include vintage year fixed effects and investor (LP) country fixed effects. We also control for the percentage of deals in the portfolio of each infrastructure fund in different industries, geographical regions, project stages, and deals backed with concession agreement. We double cluster standard errors by institutional investor and infrastructure fund, and report standard errors in brackets. *$p<.1$; **$p<.05$; ***$p<.01$.

fund because a given fund appears multiple times as associated with different investors.

As explanatory variables, we use indicators for institutional investors from the public sector: U.S. public pension funds, non-U.S. public pension funds, government agencies, and sovereign wealth funds. The omitted category is investors from the private sector. We control for the natural logarithm of the LP's AUM and for the year of their first infrastructure investment. These two variables could capture negotiating power, experience, or ability to access higher-performing GPs for reasons unrelated to investor type. The variable *#Funds* measures the total number of investments in infrastructure funds by

we show that public investors have a lower probability of exiting an infrastructure deal and hold deals longer, consistent with public institutional investors having lower performance.

investor. Since all regressions contain vintage fixed effects, the results are not driven by variation in the timing of when different types of institutional investors commit capital to the infrastructure asset class. We also include two additional control variables for fund type. First, we control for infrastructure funds labeled primarily as funds-of-funds but still holding few deals directly. Second, we control for infrastructure funds labeled as debt funds which invest primarily in debt, but hold also some equity positions. We use deal characteristics, such as project stage, location, industry, and concession agreement, as proxies for factors that capture the risk of the underlying assets.

The results in Table 8 show that public investors exhibit lower performance. Public investors hold infrastructure funds that have a 0.026 lower PME, a 1.810 percentage points lower net IRR, and a 0.038 lower multiple of invested capital. Within the sample of public investors, all four categories exhibit negative coefficients in some specifications. U.S. public pension funds invest in infrastructure funds that have a significantly lower PME and IRR. Non-U.S. public pension funds invest in infrastructure funds with a significantly lower IRR and multiple. Government agencies and sovereign wealth funds also seem to underperform compared to private institutional investors. In Internet Appendix Tables IA.13, we include indicator variables for all private institutional investors instead of public investors. We find that all private institutional investors have positive coefficients in some specifications, so the performance differences between public and private investors are not driven by only one particular group of institutional investors. For example, U.S. private pension funds, non-U.S. private pension funds, and insurance firms and banks have a 2.582, 2.004, and 0.991 percentage points higher IRR, respectively.

In Internet Appendix Tables IA.14, we perform three robustness tests. First, our analysis includes a small sample of investments in funds that are labeled primarily as funds-of-funds, but which hold few deals directly, and debt funds, which hold some equity positions. One potential concern is that we do not observe the positions of these funds obtained through the underlying funds or their debt positions, so our deal level controls do not sufficiently adjust for the riskiness of their exposure. We show that our results are robust to excluding completely funds labelled primarily as funds-of-funds or debt funds from the analysis.

Second, in our analysis, we assign equal weights to all investments in closed infrastructure funds. We do not control for committed amount as the Preqin data on dollar commitments is sparsely populated for private investors, and the data are nearly complete only for U.S. and U.K. public institutional investors. One potential concern is that the performance differences are concentrated in smaller funds that account for smaller weights in the investors' portfolio. In Internet Appendix Tables IA.14, we address this concern by assigning higher weights on investments in larger funds. In this robustness test, the observations are value weighted by infrastructure fund size. We still find that public investors exhibit significantly lower performance and the economic magnitude of the coefficients only marginally declines.

Third, our sample in Table 8 includes infrastructure funds that have been raised before 2019. However, the performance of young funds which are still not finished investing may change after they allocate the remaining capital and modify the portfolio of underlying assets. In Internet Appendix Table IA.14, we limit our attention to infrastructure funds raised in vintages before 2014, so they have existed for more than 5 years and have typically finished allocating the capital. We find economically and statistically stronger underperformance of public institutional investors. For instance, when analyzing investor-fund observations from vintages before 2014, we find that public investors obtain a 0.032 lower PME, a 1.504 percentage points lower net IRR, and a 0.040 lower multiple.[22]

The previous analysis examines the performance of institutional investors only in closed funds that report performance. As we show in Table 4, closed funds with higher percentage of quickly exited deals are more likely to report performance, so one limitation of the previous analysis is that there is a selection in the closed funds that report performance and this could affect the differences in performance among different types of institutional investor. Moreover, Preqin collects data on performance primarily via the Freedom of Information Act requests submitted to public investors, who invest in funds that private investors also invest in, as well as via a voluntary provision of performance information by other investors. One potential concern is therefore that underperforming funds selected by private investors will be far less likely to have the standard performance statistics reported in the Preqin data set.

To overcome the concerns of selection in performance disclosure, we therefore also study the universe of deals to which institutional investors have exposure, as we observe the transactions and exit rates for all closed funds (including those without public investors). The deals data are better populated for infrastructure funds than for other private funds as the average infrastructure deal is larger, subject to bidding and government concessions, and frequently covered in the news. We analyze performance on an investor-deal level by examining the probability of exiting an infrastructure investment. In Internet Appendix Tables IA.16, we find that public investors have a lower probability of exiting an infrastructure deal accessed through a closed fund, which confirms our conclusion that public investors underperform private investors. As the analysis in Table 4 shows, exiting a deal is an informative indicator of performance in our setting because the infrastructure deals of closed funds are organized in the same way as private equity funds.

[22] Internet Appendix Table IA.15 shows that our results in Tables 8 and 9 are also robust to alternative calculations of the IRR performance measure that penalize funds for delaying capital calls or not calling the entire committed amount. Thus, the differences in performance between public and private institutional investors are not driven by differences in the timeline of capital calls of their infrastructure funds.

The differences in performance between public and private institutional investors do not seem to be due to differences in risk-taking. Our deal-level controls address the possibility that public investors gain exposure to less risky infrastructure investments than private investors and that these safer assets will deliver lower returns. Prior research has documented that public investors underperform for several possible reasons. The poor selection of infrastructure funds can be due to politicized governance structures and unskilled board members (Bradley, Pantzalis, and Yuan 2016; Andonov, Hochberg, and Rauh 2018), constraints on the compensation needed to attract and retain talented staff members (Dyck, Manoel, and Morse 2019), and an inability to select or access better-performing asset managers (Sensoy, Wang, and Weisbach 2014; Cavagnaro et al. 2019). The "rationed access" hypothesis seems less likely to explain the underperformance of public investors, because most infrastructure funds are first-time funds raising large amounts of capital, but skill considerations would apply to infrastructure funds for similar reasons as to the other alternative asset classes.

In addition to these factors, the underperformance of public investors also may be driven by the stronger perceived social externalities of infrastructure assets. We hypothesize that the social externalities channel explains at least partially the underperformance of public investors because infrastructure investments have the potential to offer environmental, social, and political benefits, and we have already shown that public institutional investors with ESG preferences or regulatory pressure invest more in infrastructure over time. If these public investors have higher allocations to infrastructure due to regulation or impact investing, they may take on more marginal deals in order to meet their allocation target.

In Table 9, we shed some light on the social externalities channel by examining the extent to which ESG preferences and regulatory pressure explain the underperformance of public investors. In addition to the variables capturing UN PRI signatories, mandatory regulation, and voluntary regulation, we also create an additional fund-specific variable that captures whether an infrastructure fund is an impact fund. We follow Barber, Morse, and Yasuda (2021) and designate infrastructure funds as being impact funds if they explicitly state a dual objective of generating a positive externality in addition to earning financial returns. To classify impact funds, we implement these two approaches. First, we classify funds as impact funds if their name contains one of the following keywords: carbon, clean, climate, environment, green, impact, neutral, renewable, responsible, recycling, and sustainable. Second, we manually read the online profiles of all infrastructure funds and identify those that explicitly emphasize a dual objective. In total, we classify 93 of the 538 closed funds reported in Figure 1 as impact funds based on either of these two measures, which suggests that the proportion of impact funds in infrastructure is higher than the proportion of impact funds in buyout and VC. For instance, Barber, Morse, and Yasuda (2021) identify 91 impact VC funds versus 1,484

Table 9
Explanations of public investor underperformance

	PME			Net IRR			Multiple		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Public investor	−0.026**	−0.020*	−0.019	−1.823***	−1.475**	−1.497**	−0.038***	−0.025*	−0.025*
	[0.012]	[0.012]	[0.012]	[0.594]	[0.580]	[0.583]	[0.015]	[0.014]	[0.014]
Mandatory regulation	0.010		0.018	−2.676		−2.485	−0.068*		−0.057
	[0.036]		[0.037]	[1.802]		[1.883]	[0.037]		[0.036]
Voluntary regulation	−0.001		−0.022	0.993		−0.448	−0.011		−0.042
	[0.033]		[0.035]	[1.432]		[1.420]	[0.060]		[0.058]
UN PRI signatory		−0.027	−0.028		−1.459*	−1.346*		−0.042*	−0.039*
		[0.018]	[0.018]		[0.782]	[0.789]		[0.022]	[0.023]
Impact fund		−0.175*	−0.176*		−11.453***	−11.466***		−0.363***	−0.365***
		[0.097]	[0.097]		[3.508]	[3.531]		[0.100]	[0.100]
log investor size	0.006**	0.005**	0.005**	−0.008	−0.005	−0.011	−0.001	0.000	−0.001
	[0.003]	[0.002]	[0.002]	[0.118]	[0.103]	[0.103]	[0.004]	[0.004]	[0.004]
Year of first investment	−0.001*	−0.001*	−0.001*	−0.043	−0.025	−0.025	−0.001	−0.000	−0.000
	[0.001]	[0.001]	[0.001]	[0.033]	[0.027]	[0.027]	[0.001]	[0.001]	[0.001]
#Funds	−0.000	0.000	0.000	−0.006	0.003	0.003	0.000	0.000	0.000
	[0.001]	[0.001]	[0.001]	[0.030]	[0.028]	[0.029]	[0.001]	[0.001]	[0.001]
Fund type	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
LP country FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Vintage FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
%Deal region	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
%Deal industry	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
%Project stage	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
%Concession	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	2,342	2,342	2,342	3,021	3,021	3,021	3,853	3,853	3,853
Adjusted R-squared	.450	.469	.469	.151	.199	.200	.326	.370	.370

This table presents results of regressions in which the dependent variable is the performance of investors in closed infrastructure funds. Observations are at the investor-fund level. In columns 1 to 3, performance is measured using the public market equivalent (PME), in columns 4 to 6 using the net internal rate of return (IRR), and in columns 7 to 9 using the net multiple of invested capital. *Public investor* is an indicator variable for institutional investors from the public sector. *Mandatory regulation* and *Voluntary regulation* are indicator variables measuring whether an institutional investor faces mandatory or voluntary regulation to consider ESG factors in its investment decisions. *UN PRI signatory* is an indicator variable for investors that have signed the UN principles for responsible investing. *Impact fund* is an indicator for infrastructure funds that make investments with the intention to generate positive social and environmental impact alongside a financial return. We control for the natural logarithm of investors' size (AUM) and year of first infrastructure investment. *#Funds* measures the number of investments in infrastructure funds by investor. We include two indicator variables for infrastructure funds that do not take only equity positions in infrastructure deals, but that also act as a fund-of-funds or debt fund. We include vintage year fixed effects and investor (LP) country fixed effects. We also control for the percentage of deals in the portfolio of each infrastructure fund in different industries, geographical regions, project stages, and deals backed with a concession agreement. We double cluster standard errors by institutional investor and infrastructure fund, and report standard errors in brackets. * $p<.1$; ** $p<.05$; *** $p<.01$.

traditional VC funds reporting multiple performance measure and argue that there are even fewer impact buyout funds. Infrastructure impact funds typically focus either on assets in renewable energy, utilities, and social infrastructure industries or on assets located in developing countries. Of these 93 impact funds, 37 funds report performance statistics, and our analysis will use this subsample to examine whether the social externalities channel can explain the underperformance of public investors.[23]

Table 9 extends the empirical analysis of performance from Table 8. In columns 1, 4, and 7, we test for the social externalities by including controls for institutional investors subject to mandatory or voluntary ESG regulation. The regulation variables are not significant and do not explain the underperformance of public investors as the coefficients for public investors remain the same as in Table 8. The lack of explanatory power of the regulation variables has two likely explanations. First, as shown in Table 7, mandatory regulation has a similar impact on the number of investments made by public and private institutional investors, so it does not lead to differences in exposure. Second, a number of ESG regulations have been enacted recently and they may lead to performance differences going forward.

In columns 2, 5, and 8 of Table 9, we find that UN PRI signatories and impact funds have lower performance in infrastructure. UN PRI signatories have a 1.459 percentage points lower net IRR and a 0.042 lower multiple. The underperformance of impact funds is economically larger, and around 0.175 PME points, 11.453 IRR points, and 0.363 multiple points; these magnitudes are in line with prior evidence on the underperformance of VC impact funds (Barber, Morse, and Yasuda 2021). The explanatory power of these two proxies for ESG preferences is not due to heterogeneous exposure to assets in different regions or industries, as we control for the percentage allocation of each fund to deals in different regions and industries. Thus, our results do not imply that UN PRI signatories and impact investors underperform because they invest in renewable energy or emerging economies, but rather that their underperformance seems to be due to investing in marginal deals within these industries or regions that have a lower financial return and may not have received funding from traditional infrastructure funds.

These two proxies for ESG preferences explain approximately 30% of the underperformance of public investors in infrastructure. In particular, the coefficient for public investors in the PME regression decreases from −0.026 in column 1 to −0.019 in column 3. The UN PRI signatories variable explains part of the underperformance of public investors, because public investors that have signed the UN PRI make more infrastructure investments

[23] Both classification approaches if used separately would lead to a similar sample of impact funds. The name of 27 of 37 funds contains one of the impact keywords, while the profile of 29 of 37 funds describes a dual objective to generate a positive impact in addition to financial returns; 18 funds have both. While this procedure verifies that an infrastructure fund has a name or mission consistent with impact investing, here we do not make any attempt to verify the nonfinancial outcomes of their infrastructure investments.

(see Table 7). Similarly, impact funds explain part of the underperformance of public investors, because public investors have more exposure to impact funds, not because public investors pick underperforming impact funds. In Internet Appendix Tables IA.17, we show that public investors are more likely to commit capital to impact funds, while the interaction term between public investors and impact funds in the performance regressions is not significantly negative.

In conclusion, our proxies for nonfinancial objectives and regulatory pressure explain 25%–40% of the increased allocation by public investors as well as 30% of their underperformance. The remainder can likely be attributed to poor fund selection or nonfinancial objectives that are not captured by our relatively simple proxies. The social externalities channel is especially relevant for infrastructure assets, because these assets are closely related to government spending and regulation but managed by profit-maximizing intermediaries. We show that public institutional investors bear part of the costs by accepting lower returns when investing in these assets that are characterized by positive externalities and government involvement.

4. Implications for Institutional Investors

4.1 Deal exit rates across investment structures

We have documented that closed funds, the main structure by which investors gain access to infrastructure, do not in fact deliver long-term reliable income streams. If investors indeed include infrastructure in their portfolios in order to obtain stable cash flows in the long run, other investment structures may be better positioned than closed funds to match their expectations. We do not observe cash flows for listed funds, open ended funds, or direct deals, so we cannot compare the returns of closed funds with these investment structures. We can, however, compare the holding period and exit probabilities.

In Figure 5 and Table 10, the unit of observation is the investor-deal level, and we study the probability that an investor exits an infrastructure investment. Figure 5, panel A reports Nelson-Aalen cumulative hazard rates of exits over time by investment structure. The event of interest is a sale transaction that results in a full (not partial) exit of an equity position in an infrastructure asset. We find that institutional investors have experienced an exit on more than 90% of the deals accessed through closed funds after 14 years. The other structures do not have a predefined ending term and thus do not face an incentive to exit deals quickly. Institutional investors gaining exposure through listed funds, open-ended funds, and direct deals have experienced exits on around 27%, 50%, and 37% of their deals, respectively.

In Table 10, we estimate the differences in exit rates across investment structures using a Cox proportional hazard model. The hazard event of interest is defined again as a full sale of an infrastructure asset during a year. We estimate the hazard rate of exiting an asset, defined as the probability that an exit will come to fruition in year t conditional on it not becoming complete prior to year t.

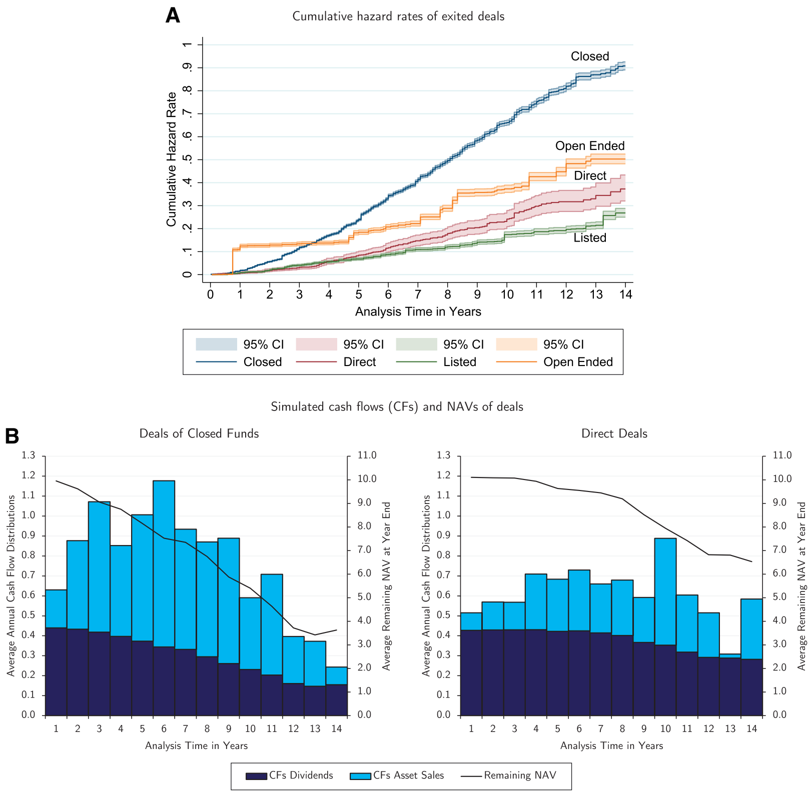

Figure 5
Exited deals and simulated cash flows by investment structure
In panel A, we present the Nelson-Aalen cumulative hazard function by investment structure. The unit of observation is investor-deal and the event of interest is a sale transaction that results in a full exit (disposition) of an asset. We plot the cumulative hazard rate and the corresponding 95% confidence interval. In panel B, we simulate the cash flows by investment structure. In the simulation, the investment and exit dates remain the same, but all investors hold the MSCI World Infrastructure Index. The simulation includes all transactions after January 1999, assumes that all deals receive an investment capital of $10, and uses the "price" and "gross" series of the index to decompose the returns over time into dividends and capital gains. Observations are at the investor-deal-year and we combine all monthly cash flows into one annual cash flow for each investor-deal observation, and then average across investor-deal observations within the year. Time is measured relative to the investment month (so not calendar year). The left axis shows the average annual cash flows to investors, while the right axis reports the remaining NAV.

In this setting, t refers to the number of years after the purchase transaction and it measures event time rather than calendar time. Estimation of the model delivers coefficients that can be interpreted as hazard ratios. A hazard ratio lower than one indicates that as the value of the covariate increases, the hazard rate of exiting a deal decreases. We cluster standard errors by institutional investor.[24]

24 In Internet Appendix Tables IA.18, we show that our results are robust to clustering standard errors by infrastructure asset. This robustness test accounts for the fact that multiple institutional investors can invest in the same asset.

Table 10
Exiting a deal and investment structure

	(1)	(2)	(3)	(4)
Direct deal	0.491***	0.478***	0.504***	0.490***
	[0.077]	[0.074]	[0.078]	[0.076]
Listed	0.291***	0.307***	0.296***	0.311***
	[0.023]	[0.023]	[0.024]	[0.024]
Open ended	0.698***	0.699***	0.700***	0.699***
	[0.033]	[0.033]	[0.033]	[0.033]
Public investor	0.926**	0.936*	0.927**	0.938*
	[0.033]	[0.032]	[0.033]	[0.032]
UN PRI signatory		0.972		0.973
		[0.047]		[0.047]
Impact fund		0.551***		0.558***
		[0.036]		[0.036]
Mandatory regulation			0.630***	0.666***
			[0.080]	[0.079]
Voluntary regulation			1.041	1.014
			[0.089]	[0.086]
log investor size	0.999	1.001	0.999	1.000
	[0.009]	[0.009]	[0.009]	[0.009]
Year of first investment	0.984***	0.984***	0.985***	0.985***
	[0.003]	[0.003]	[0.003]	[0.003]
#Funds	0.998	0.998	0.998	0.998
	[0.002]	[0.002]	[0.002]	[0.002]
Concession	1.652***	1.650***	1.643***	1.642***
	[0.071]	[0.071]	[0.071]	[0.070]
Greenfield	0.711***	0.721***	0.713***	0.722***
	[0.022]	[0.022]	[0.023]	[0.022]
Brownfield	0.664***	0.662***	0.663***	0.661***
	[0.022]	[0.022]	[0.022]	[0.022]
Home deal	0.701***	0.695***	0.704***	0.696***
	[0.042]	[0.040]	[0.043]	[0.041]
#Investors	0.956***	0.956***	0.956***	0.956***
	[0.007]	[0.007]	[0.007]	[0.007]
Investment stake	0.987	1.032	0.992	1.035
	[0.042]	[0.045]	[0.042]	[0.046]
LP country FE	Yes	Yes	Yes	Yes
Deal region FE	Yes	Yes	Yes	Yes
Deal industry FE	Yes	Yes	Yes	Yes
Observations	79,705	79,705	79,705	79,705

This table presents results of a survival analysis using the Cox proportional hazard model. The event of interest is a sale transaction that results in a full (not partial) exit of an equity position in an asset. We present the hazard ratios. *Direct deal* is an indicator variable for direct investments in infrastructure deals. *Listed* and *Open ended* are indicators for deals accessed through listed and open-ended funds. The omitted investment structure is closed funds. *Public investor* is an indicator variable for institutional investors from the public sector. The ESG regulation and preferences variables are the same as in the previous table. We control for the natural logarithm of investors' size (AUM), year of first infrastructure investment, and the number of fund investments. *Concession* is an indicator variable equal to one if an investor enters a concession deal with the government. *Greenfield* and *Brownfield* are indicators for project stage (the omitted category is secondary stage). *Home deal* is an indicator for deals located in the same country (state) as the investor. *#Investors* counts the total number of investors in the same deal (multiple institutions investing through the same infrastructure fund are not counted multiple times). *Investment stake* is the ownership stake of an infrastructure fund or direct investor. We control for LP country, deal industry, and deal region fixed effects. We cluster standard errors by institutional investor and report standard errors in brackets. * $p < .1$; ** $p < .05$; *** $p < .01$.

In the Cox proportional hazard model, the coefficient estimates are robust to any baseline hazard function, which implies that the specification is robust to time-specific common factors, analogous to controlling for year fixed effects (Dinc and Gupta 2011).

In the analysis, we focus on the indicators for deals accessed through listed funds, open-ended funds or direct investments versus closed funds. Direct deals offer more flexibility in exit decisions. When investing through funds, institutional investors generally do not have the power to influence the timing of exit decisions, whereas when they invest directly they can make such decisions. Based on column 4, direct deals have 51.0% lower exit rates, which suggests that the direct investors can make longer-term commitments. Within the investments through funds, we find that listed and open-ended funds provide more long-term exposure to infrastructure assets. Based on column 4, listed and open-ended funds have a 68.9% and 30.1% lower probability of exiting a deal as compared to closed funds.[25]

We arrive at the conclusion that other investment structures than closed funds are better suited to provide long-term exposure to infrastructure assets after controlling for differences in the selection of projects and investor characteristics. First, we control for deal industry and location through the inclusion of fixed effects.[26] We also control for home deals, which is an indicator variable based on the location of the deal relative to the location of the institutional investor. Since the United States is a very large country in our sample with a geographically disperse network of institutional investors, we define the *Home Deal* variable for U.S. investors as deals located in the same state (not country) as the institutional investor. Controlling for home deals is important as institutional investors have a 30% lower probability of exiting a local deal as compared to a deal located in another country. This relation is not unique to public investors as both public and private investors have a lower probability of exiting deals located in their home country.

Second, we control for concession agreement, project stage, and ownership structure. The coefficients for the greenfield and brownfield variables indicate that these riskier projects require a longer time for development before they can be exited, while fully operational secondary deals are more liquid and transact faster. Deals backed by a concession exhibit a higher probability of exit, which implies that a concession agreement increases the liquidity of a deal. Regarding the ownership structure, we observe a lower probability of exiting a deal when multiple investors participate in the transaction.

25 Our sample of closed funds also includes a small number of co-investment vehicles. We observe only 19 closed infrastructure funds (29 investor-fund observations; 272 investor-deal observations) organized as coinvestments or separately managed accounts. Begenau and Siriwardane (2020) also find that coinvestments have not been a large part of institutional private equity portfolios over the 1990–2018 period. We do not expect that coinvestments will have different exit decisions and cash flows than standard closed funds. GPs typically have "drag-along-rights" and retain the power to decide when to exit the underlying deals in a coinvestment (Ivashina and Lerner 2019). The "drag-along-rights" ensure that institutional investors owning a share of the underlying deals through a coinvestment also sell their investment stake at the same time when the GP wants to exit.

26 One potential limitation of the region fixed effects is that even countries located in the same region can have different policies and regulations. In Internet Appendix Tables IA.19, we replace the deal region fixed effects with deal country fixed effects and show that our results remain the same when we include more precise country fixed effects.

Third, we include an indicator variable for public institutional investors. Based on column 4, public investors exhibit a 6.2% lower probability of exiting an infrastructure deal in year *t* if they have not exited it previously. In Internet Appendix Tables IA.16, we show that the lower exit rates of public investors are driven by assets to which they gained exposure through closed funds. Since closed funds have an ending term and stronger incentives to exit a deal faster, the lower exit rates of public investors in these assets are in line with our result that public investors underperform private investors in infrastructure. We also include indicator variables for institutional investors with ESG preferences or subject to regulation. Based on column 4, investors committing capital to impact funds have 44.2% lower exit rates. This result suggests that our classification indeed captures impact funds that hold deals longer in order to realize nonfinancial objectives in addition to financial returns. We also find that investors under mandatory ESG regulation hold assets longer and have 34.4% lower exit rates, which potentially implies that investors want to keep infrastructure assets longer in their portfolio as it enables them to meet the ESG regulatory criteria. The lower exit rates of impact investors and investors under mandatory ESG regulation are also in line with the prior evidence on underperformance of institutional investors with ESG considerations. These investors face systematic exposure to lower quality deals which are less likely to allow for an early, successful exit.

These disposition patterns are consistent with differences in managerial compensation-related incentives across the different investment structures. GPs of closed funds earn management fees either on amount of committed capital in the investment phase of the fund or on the amount of invested capital after the initial phase, while GPs of open ended funds or listed funds earn management fees based on the amount of assets under managements (these NAV-based management fees act to some extent like carried interest because the amount of fees increases as asset values go up). GPs of closed funds also earn carried interest only upon a successful exit from a deal, while GPs of listed and open ended funds structure earn carried interest based on the performance within the last period (Towers Watson 2011; OECD 2014). The compensation of managers employed in internal (direct) investment teams of institutional investors includes some bonus structure, but it does not depend on the disposition of assets. Based on these compensation-related incentives, GPs of closed funds have the strongest incentives to exit the best deals quickly, while listed and open ended funds have incentives to grow the amount of AUM over time.

Overall, other investment approaches offer more long-term exposure to infrastructure assets and could potential deliver more stable cash flows to investors. One limitation of this analysis is that we do not have data on the cash flows of the underlying infrastructure assets and, thus, cannot directly examine the volatility, cyclicality, and correlations of these assets. However, even though we cannot examine the cash flows on an asset level, we provide two additional analyses that demonstrate that the closed fund structure delivers relatively more volatile and procyclical cash flows than the other investment structures.

In the first analysis, we use simulated cash flows based on listed infrastructure assets. In the simulation, we assume that the investment and disposition dates remain the same as in Figure 5, panel A, but all investors buy the MSCI World Infrastructure index at the end of the month. The starting date of the index is January 1999, so we include in the simulation all investor-deal observations with an investment date after January 1999. We use the “price” and “gross” series of the index to decompose the returns into dividends and capital gains. This decomposition essentially splits the cash flows to investors into dividend strips and capital gain strips from asset sales (Gupta and van Nieuwerburgh 2021). In the simulation, all deals receive the same investment amount of $10 and generate cash flows based on the same time series of dividends and capital gains. Thus, differences in the cash flows to investors arise only from the differences in the timing of exits across structures (and not from the riskiness of assets).

Panel B of Figure 5 presents the simulated cash flows for the two main structures, closed funds and direct deals. The unit of observation is investor-deal-year and time is measured since the investment month. For these graphs, we combine all simulated monthly cash flows into one annual cash flow for each investor-deal observation, and then average across investor-deal observations within the year. The majority of cash flow distributions of closed funds come from asset sales, while the distributions of direct deals are more stable over time and incorporate relatively more dividend payments. In addition, the remaining NAV of closed funds’ deals is around $3.60 after 14 years and is significantly lower than the remaining NAV of around $6.50 of direct deals. The simulation suggest that the distributions of direct deals behave more like operational cash flows or dividend strips, while the distributions of closed funds behave more like asset disposition cash flows or capital gain strips (Gupta and van Nieuwerburgh 2021). The asset disposition behavior of closed funds leads to more volatile cash flows than the behavior of other structures, while holding the underlying investments constant. In Internet Appendix Table IA.20, we examine the sensitivity of simulated cash flows to the business cycle showing conclusively that the disposition pattern of closed funds is procyclical. The cash flows of other investment structures also may be procyclical, but the coefficients are not precisely identified.

In the second analysis, Internet Appendix Tables IA.12 shows that the investments of closed funds use a relatively higher amount of leverage. Deals of closed funds have a mean leverage of 65% (median 71%), which is higher than the leverage of direct deals (mean 57%, median 60%), listed funds (mean 62%, median 64%), and open-ended funds (mean 57%, median 64%). The amount of leverage employed by closed infrastructure funds is similar to the amount of leverage used by buyout funds. For instance, Axelson et al. (2013) show that buyout transactions have a mean 69% and median 70% leverage.

In levered transactions of closed funds, the excess cash flow generated by the deal is typically used to pay down acquisition debt over time rather than passed through to the LPs (Axelson et al. 2013). Thus, the higher leverage of deals executed by closed funds implies that relatively more cash flows from the underlying assets are used to repay debt rather than provide dividend- style payments to the institutional investors.

We postulate that several additional factors will make the annual distributions of deals implemented by closed funds even more volatile. For instance, we assume that all assets generate the same capital gains by holding the MSCI World Infrastructure index. However, Table 4 shows that closed funds exit their best-performing deals earlier. Thus, one can expect that the cash flows from asset sales in the first 10 years will be even higher, while only underperforming assets will remain in the portfolio after 10 years. This suggests that the dividends, remaining NAV, and cash flows from asset sales will be even lower than in our procedure. Further, Table 2 shows that closed funds invest relatively more in greenfield and brownfield assets, which are commonly considered riskier and do not generally distribute cash flows back to the investors in the initial years of an investment. Thus, our simulation likely overestimates the dividends in the earlier years relatively more for closed funds than for other investment structures. The shape of cash flows distributions from closed funds in Figure 5, panel B, already resembles the shape from Figure 3, panel C, and we expect that the cash flows will get even closer after accounting for these two factors.

In conclusion, the data do not allow us to draw inferences about the stability of the cash flows generated by the assets that underlie infrastructure investments. Prior research on listed infrastructure assets and closed infrastructure funds documents a relatively high exposure to risk factors (Van Nieuwerburgh, Stanton, and de Bever 2015; Gupta and van Nieuwerburgh 2021). However, we document that the closed fund structure relies more on asset dispositions rather than operational cash flows and makes the cash flows from the underlying assets even more volatile and procyclical than the other investment structures. The development of infrastructure as an asset class in the long run will depend on establishing an investment structure that takes into account the specific nature of the underlying assets and investor objectives rather than just copying the traditional private equity model.

4.2 Benchmarking infrastructure funds

Another implication of our analysis is that the underperformance of public investors can be seen as a value transfer to the underlying assets and the GPs managing them. Public investors have continued to increase their allocation to closed funds over time despite the weak risk-return characteristics of these funds. If public investors did not increase their allocation over time, fewer infrastructure assets would have received financing, and the GPs would have collected a lower amount of fees. This underperformance will negatively affect public pension funds in particular as they have explicit liabilities and need to report their funding status. Depending on whether unfunded pension liabilities will be ultimately remediated through contribution increases or benefit cuts, taxpayers, pension plan members, or a mix of both will incur the costs. The cost for the underperforming government agencies and sovereign wealth funds is directly covered by taxpayers.

We cannot identify how much of the underperformance is flowing to infrastructure assets that otherwise would not have received funding versus GPs in form of fees. However, the fees for investing in closed infrastructure funds seem substantial, and GPs are one of the main beneficiaries from the growth of infrastructure as an asset class. Based on the data from CEM Benchmarking, the median infrastructure costs for closed funds are 167 basis points (bps) per year, which is higher than private real estate fund costs of 95 bps, but lower than private equity investment costs of 239 bps. These values include only management fees, as the performance fees are directly subtracted from returns in the CEM data.[27]

If institutional investors continue in the future to use closed funds as their main investment structure, then these vehicles should be compared with other private funds that have similar risk-return characteristics. Given our findings that the cash flow profiles of infrastructure fund investments are similar to the profiles of general private equity buyout fund investments and real estate investments, we consider how the infrastructure fund investments made by public investors have performed relative to their own investments in other private markets. We note that this is a partial-equilibrium calculation, in the sense that if an investor were to switch an infrastructure allocation to another private asset class, the investor would receive the return on the marginal private investment, which is likely lower than the average.

In Table 11, we compare the performance of investments in infrastructure funds with the investments in other private funds made by the same public investor and in the same vintage year. Public investors invest in buyout funds that deliver a 5.78 percentage point (14.31 – 8.53) significantly higher IRR than their own infrastructure funds. Based on our estimates, public investors have at least \$277 billion invested in infrastructure assets.[28] The difference in IRR relative to buyout funds would imply an annual loss of \$16.01 billion. The difference in IRR relative to VC funds would imply only a slightly smaller annual loss, although the properties of VC investments and infrastructure investments are sufficiently different that this is a less appropriate comparison. The difference in IRR relative to real estate funds is smaller and would imply an annual loss of

27 CEM Benchmarking collects anonymous information on the amount of AUM, asset allocation, investment costs, returns, and benchmarks for institutional investors from the United States, Canada, Europe, and Australia.

28 The \$277 billion estimate is equal to 57.0% of the \$486 billion AUM reported in Figure 4. We assume that the 57% share of public investors in the AUM is given by their share in the investor-deal observations in 2019, presented also in Figure 4.

Table 11
Comparison of investments in infrastructure with investments in other funds

	Net IRR				Multiple			
	Obs.	Infra	Other	Diff.	Obs.	Infra	Other	Diff.
Infrastructure vs. buyout	719	8.53	14.31	−5.78***	933	1.29	1.50	−0.21***
Infrastructure vs. VC	427	8.53	13.99	−5.46***	555	1.29	1.66	−0.39***
Infrastructure vs. real estate	516	8.45	10.18	−1.73**	638	1.28	1.29	−0.01

This table compares the performance of investments in infrastructure funds with the investments in buyout, venture capital (VC), and real estate funds made by the same public institutional investor. We match the infrastructure investments with buyout, VC, and real estate investments made by the same public investor and in the same vintage year. We present the average net IRR and multiple of invested capital delivered by infrastructure, buyout, VC, or real estate funds. The number of observations changes because it depends on making investments in infrastructure, buyout, VC, or real estate in the same vintage year and on the availability of performance data for these investments. In the *Diff.* columns, we present the difference between the performance that public investors earn on their infrastructure fund investments minus the performance on their other fund investments. $*p<.1$; $**p<.05$; $***p<.01$ indicate significance of the difference based on a t-test.

only $4.79 billion relative to what public investors could have achieved if they could have committed more capital to their existing real estate funds instead of investing in infrastructure funds. These estimates provide just an indication of the value transfer, and we caution that the net IRR equals the rate of return experienced by investors if and only if dividends generated by the investment are reinvested and earn that same rate of return (Phalippou 2008; Kaplan and Sensoy 2015).

In sum, public investors have been increasing their allocation to closed infrastructure funds over time despite their underperformance, which is substantial relative to comparable risk-return investment opportunities in the private markets. If institutional investors still continue to use closed funds as their main investment structure, then these vehicles should be benchmarked against other private funds that have similar risk-return characteristics.

5. Conclusion

Institutional investors are becoming increasingly active in the provision of capital to infrastructure assets. The commonly heard explanation for why institutional investor demand for infrastructure has risen so much is that infrastructure is a new asset class with attractive attributes, such as low sensitivity to swings in the business cycle, little correlation with equity markets, and long-lasting, inflation-linked cash flows. Yet even though investors expect infrastructure to deliver long-term stable returns, we find that they gain exposure to infrastructure in large measure through finite-horizon private funds. The cash flows delivered by these infrastructure funds display similar volatility and cyclicality as the cash flows of other private equity investments, and their performance depends to a similar extent on quick deal exits. Thus, even in cases in which the underlying infrastructure assets are more tangible, belong to highly regulated industries, and in some cases are even backed by long concession agreements, the business model of closed funds does not translate the differences in the underlying assets into different risk-return properties.

Despite both weak performance and failure to match the supposed characteristics of infrastructure investments, infrastructure funds have increased their AUM from $59 billion in 2008 to $486 billion in 2019. This increase in assets is driven especially by the increased allocation of public institutional investors, which perform worse than private institutional investors even after controlling for underlying deal characteristics. We find that persistent differences in performance in infrastructure are in part attributable to differences in implicit adoption of nonfinancial objectives across investors, consistent with a willingness to make more marginal investments. ESG preferences and regulation that either encourage or mandate ESG considerations explain 25%–40% of the higher number of infrastructure investments made by public investors and around 30% of their underperformance.

The evidence that private investors perform better in infrastructure at present, when this asset class is still young and growing, is in line with the evidence that private investors made VC investments with superior performance in the 1990s, before the venture industry matured (Lerner, Schoar, and Wongsunwai 2007; Sensoy, Wang, and Weisbach 2014). However, a major difference is that an investor focus on social externalities is a key driver both of increased exposure to infrastructure and of financial underperformance in infrastructure. The finding that public investors' infrastructure investments are likely not on the efficient frontier has important implications as public investors are scaling up the extent of their infrastructure investing. While infrastructure investments could obviously have societal benefits, the underperformance reflects a price that is paid to create these benefits, with the transfers going either to the infrastructure assets or to the GPs through fees. This cost will be borne by taxpayers or pension beneficiaries or both.

In the short run, a commitment by some investors to nonfinancial objectives might partly overcome the headwinds from the performance of the asset class in the raising of capital. However, the failure of closed funds to match investor expectations and the underperformance of public investors imply that society runs the risk of not being able to attract sufficient capital in competitive private markets to cover the infrastructure funding gap. Future research should examine the risk-adjusted performance and cash flows on an infrastructure asset level in order to understand whether alternative investment structures could meet investors' expectations. The closed fund model seems appropriate for greenfield and brownfield projects that require close monitoring and rapid restructuring, but is less suitable for secondary projects that are operational and generating cash flows. Other investment structures, such as open-ended funds, listed funds, and direct deals, may be more suitable for long-term investment strategies in operational infrastructure assets, as our exit rates analysis suggests that the other investment approaches hold infrastructure deals longer and their business models may better match the expectations of institutional investors. If infrastructure assets are in fact more stable than other assets, these investment structures may be a more natural place to look for diversifying, long-term, acyclical, and inflation-hedged cash flows. The development of alternative fund structures for mature cash-flow-generating infrastructure assets will be important if institutional investment is to continue to support infrastructure on financial grounds.

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