CHAPTER 1

Infrastructure Demand and Investment Funds

Bijli, sadak aur paani (Hindi for "Electricity, roads and water")
—Election slogan in India, 2004

Roads probably constitute the earliest human demand for infrastructure, and the earliest known constructed roads have existed in Ur in modern-day Iraq since 4000 BC.[1] Indeed, the pyramids couldn't have been built without the roads on which the giant limestone blocks were dragged around between 2600 and 2200 BC. Civilizations advanced or declined around the quality of their road networks. The ancient Roman, Persian, Indian, and Chinese civilizations all built road networks that allowed them to rapidly transport military units while simultaneously encouraging commerce and trade. Trade routes joined the empires of China, India, Asia Minor, North Africa, and Rome. The next major infrastructure development came from the great discoveries of electricity and its applications by Benjamin Franklin, Nikola Tesla, André-Marie Ampère, Michael Faraday, Thomas Edison, and many others in the eighteenth and nineteenth centuries.

In the modern era, the term *infrastructure* refers to a wide array of industries with different characteristics. Traditionally, *infrastructure* refers to the following sectors of the economy: transportation, energy, telecommunications, water, and sanitation. *Transportation* refers to road, rail, airports, and ports. *Energy* refers to oil, gas, petrochemicals, and electricity generation, transmission, and distribution. *Telecommunications* refers to fixed lines and mobile telephony. Recently, information technology infrastructure that refers to the physical hardware used to connect computers and users is sometimes grouped with traditional infrastructure.*

Commentators have also grouped social infrastructure like schools, prisons, hospitals, and courts under the rubric of infrastructure.[2] Grouping fundamentally different industries like mobile telephony with schools and prisons obscures the fact that the risk and return profile of these assets is very different. Consequently these assets demand different investment strategies. We therefore need consistent criteria for classifying infrastructure industries.

In this book, I use asset characteristics as classifying criteria. Using asset characteristics as an analytical scalpel yields insights into infrastructure asset risks that help us design optimal investment strategies. For example, electricity generation using coal, oil, and nuclear fuel differs in fundamental and important ways from alternative energy sources like solar, wind, and so on. Chapter 2 is entirely devoted to this topic. In this chapter I choose the traditional infrastructure industries which Chapter 2 shows possess distinct characteristics—electricity, transportation (road and rail), water and sanitation, fixed-line telecommunication, and pipelines—for analyzing demand across different countries.

Using two distinct methodologies for analyzing infrastructure demand, I make the case that demand is growing and requires large investments that private investors can provide. Demand analysis shows which sectors and geographical areas are likely to be attractive to investors. Furthermore, the returns from these investments match the needs of pension funds and insurance companies in particular and therefore offer attractive investment opportunities.

AN OVERVIEW OF INFRASTRUCTURE DEMAND

Infrastructure demand refers to the investment necessary to satisfy retail consumer demands as well as producer or industry demands based on projected GDP growth. This makes sense because it's reasonable to assume that as disposable income rises, demand for a better quality of life in terms of electricity, water, sanitation, telecommunications, and transportation (air, sea, road, and rail) should increase. Industry, too, demands increased electricity, transportation, telecommunication, energy, commodities, and

* In some definitions, *information technology infrastructure* refers to everything that supports the flow and processing of information. Therefore, phone lines, data lines, computer hardware, software, and devices that control transmission paths would all qualify as information technology infrastructure.

EXHIBIT 1.1 Historical Change in Composition of Infrastructure Stocks

	1960	1970	1980	1990	2000	2010
Electricity	22%	32%	40%	43%	44%	42%
Roads	47%	46%	45%	44%	44%	43%
Rail	29%	19%	13%	9%	6%	5%
Telecom	2%	3%	3%	4%	6%	10%
Total	100%	100%	100%	100%	100%	100%

Source: M. Fay and T. Yepes, "Investing in Infrastructure: What Is Needed from 2000 to 2010?" *World Bank Policy Research Working Paper 3102*, 2003.

other inputs to keep pace with growth in its output. Demand, however, is unlikely to be uniform across industries and countries. This has been true historically and is likely to persist in the future. An analysis of sectoral and geographical demand is helpful to investors for targeting the appropriate industry and country. Exhibit 1.1 shows the change in worldwide composition of infrastructure stocks from 1960 to 2010. Water and sanitation is excluded because of lack of data.

Exhibit 1.1 shows that the share of rail dropped from a third to a mere 5 percent and the share of electricity doubled while telecommunications quintupled, albeit from a low 2 percent to 10 percent, over the 50-year period. Therefore, any linear extrapolation into the future based on past trends even in mundane infrastructure must be interpreted with caution.

A complex interplay of factors influences demand in different infrastructure sectors. Some of these include technology, substitutability (mobile for fixed line, road for rail), complementarities (electricity generation to electric trains), sectoral structure (number and strength of established firms resistant to change), macroeconomic factors (GDP per capita), and so on. Technology has affected demand for fixed-line telecommunications with mobile telephony replacing fixed lines in high income countries and leapfrogging investments in fixed lines in low- and middle income countries. Technology also influences oil, gas, and electricity generation with the development of alternative energy sources, although these are not likely to catch up with traditional oil, gas, and coal even by 2030.[3] Exhibit 1.2 displays the factors affecting demand for each sector and the interaction of the sectors.

In addition to the factors and interactions shown in Exhibit 1.2, investors must take into account cultural attitudes and government policy encouraging or discouraging particular infrastructure industries in order to forecast infrastructure demand with any degree of precision. The next section develops broad estimates of infrastructure investments up to 2030.

EXHIBIT 1.2 Infrastructure Demand Drivers and Interactions

Industry	Substitutes	Complements	Demand Interaction with Other Factors
Electricity generation using coal, oil, gas, hydro, and nuclear fuels only	Generation using wind, geothermal, solar, fuel cells Generation using waste recycling	Telecom, water services for metering, billing, and service provision High-speed rail network	Demand sensitive to GDP growth Nuclear, coal, and oil demand sensitive to environmental considerations such as reduction of pollution, disposal of nuclear waste
Road	Rail—transportation of basic commodities and intermediate goods Telecommuting substitutes for road and rail travel. Effect is ambiguous for long-distance travel; for example, off-shoring might increase or decrease local road/rail demand	Complements right of way for electricity transmission, fixed telecom lines	Demand unlikely to be sensitive to technological changes Demand sensitive to GDP growth, number of automobiles, cost of auto fuel, and disposable income
Rail	Road Telecommuting	Complements right of way for electricity transmission, fixed telecom lines, fiber optic cable	High-speed technology Demand sensitive to cost of fossil fuels Demand sensitive to environmental considerations for reduction in pollution and conservation of fossil fuels
Telecom—fixed lines	Mobile, IP telephone, WWAN		Demand extremely sensitive to technology
Water			Demand sensitive to environmental considerations—climate change, water conservation
Sanitation			Demand sensitive to environmental considerations—reducing pollution

Source: Author analysis.

Note that forecasts tend to lose accuracy as the forecasting period increases, and a forecasting period up to 2030 is still very long. The forecasts presented are therefore meant to be interpreted as providing broad estimates and are meant to provide insights into asset allocations across industries and geographies.

Forecasting Infrastructure Demand

In this chapter I explore the methodology followed by the World Bank and the Organisation for Economic Co-operation and Development (OECD) to forecast investments for new assets as well as maintenance of existing infrastructure assets, using historical investment patterns as a percentage of gross domestic product (GDP). In addition, I use gross national income (GNI) to compare infrastructure stocks across countries with different levels of GNI. In the GNI method I extrapolate the future demand in low and middle income countries to match infrastructure in the high income countries.

In the percentage of GDP methodology, total spending on new infrastructure and maintenance varies with the GDP of countries. Developing countries need to spend a higher proportion of their GDP on infrastructure because of their lower infrastructure stocks and their greater growth rates. Estimates for new investments in developing countries range from 4 percent of GDP in the World Development Report[4] to 3.2 percent in Fey and Yepes (2003). Middle income countries spend about 2.6 percent of GDP while high income economies spend about 0.4 percent of GDP on new infrastructure investment. The estimates for maintenance follow a similar pattern, with low income countries estimated to spend about 3.73 percent, middle income countries about 2.5 percent, and high income countries about 0.42 percent.

Apart from the demand for new infrastructure stocks, investments are also required for maintenance and replacement of existing stocks. Although total investments required in infrastructure should include funds for maintenance, maintenance funds essentially comprise costs required to keep the assets functioning smoothly. For the purposes of analyzing investment strategies, these costs determine working capital requirements and available free cash flows which in turn determine the return over investment. High maintenance costs naturally reduce free cash flow and returns. I do not consider maintenance funds further here since maintenance funds are not investments and do not translate into claims on assets. Suffice it to say that maintenance funds for electricity, road, and rail make up about 2 percent of the replacement cost of the capital stock, 3 percent for water and sanitation, and up to 8 percent for telecom fixed lines.[5]

Should we consider funds for replacement of existing infrastructure stocks? The amount of funds needed for the replacement of existing infrastructure depends on the level of existing infrastructure stock, the total life of the stock, and the rate of depreciation. For example, if we assume that the life of roads is 30 years and the rate of depreciation is spread out equally over the 30 years, then 1/30 of the road stock needs to be replaced every year. In the case of developing countries, since the level of stocks is low to begin with and the need to develop new infrastructure is high, funds needed for replacement as compared to new investments are likely to be low. In the case of developed countries, however, replacement funds are likely to constitute a large proportion of infrastructure spending. For investors, however, it is important to note that investment in replacement assets must translate into clearly defined claims over the assets.

Unfortunately, replacement investments do not readily translate into claims over the assets because of the lumpy nature of infrastructure assets, although there are certainly creative solutions. For example, it would be difficult to segregate revenues from replacing or adding an additional lane on a road, but a portion of the road could be replaced and converted into a toll road; or a portion of a transmission grid could be replaced—for example, from overhead lines to underground cables—and revenues generated from the replaced portion separated from revenues from the rest of the grid. This needs evaluation on a case-by-case basis and is akin to investing in existing assets.

I interpret the investment needs identified here as the demand for stocks of infrastructure, such as miles or kilometers of paved highways or pipelines or rails. I do not consider their intensity of use. In developing countries the intensity of use is typically higher than in high income countries. This lowers the overall demand for infrastructure stocks. It also increases revenues from subscribers for the same level of fees but at the same time increases maintenance costs. The net effect on operating profits and free cash flow available to investors as return on investment depends on relative rate of increases in revenues and costs, which in turn depends on the intensity of use. This raises the issue of the optimum intensity level that maximizes revenues while simultaneously limiting maintenance costs. The fees charged to subscribers are subject to market conditions and political constraints, especially in the case of infrastructure. The monopoly nature of infrastructure services implies that customer segmentation strategies (i.e., providing a higher level of service to higher paying customers or denying service to some users) are difficult for political reasons. Strategies for achieving optimum intensity levels through fees, user incentives, user segmentation, and so on, therefore require detailed analysis on a case-by-case basis. In the next sections I explore the percentage of GDP methodology, followed by the GNI methodology.

EXHIBIT 1.3 Estimated Annual Infrastructure Demand in US$ Billions (Percent of GDP Methodology)

	2000–2010	Percent of World GDP	2010–2020	Percent of World GDP	2020–2030	Percent of World GDP
Annual world GDP	$57,253.52		$76,184.74		$100,502.79	
Road	$220.00	0.38	$245.00	0.32	$292.00	0.29
Rail	$49.00	0.09	$54.00	0.07	$58.00	0.06
Telecom	$654.00	1.14	$646.00	0.85	$171.00	0.17
Water	$576.00	1.01	$772.00	1.01	$1,037.00	1.03
Electricity—transmission and distribution	$127.00	0.22	$180.00	0.24	$241.00	0.24
Electricity—generation	$377.87	0.66	$495.20	0.65	$653.27	0.65
Grand Total	$6,848.34	3.5	$1,897.00	3.14	$1,799.00	2.44

Source: Infrastructure to 2030: Telecom, Land Transport, Water and Electricity (OECD Publishing, 2006); author analysis.

Percentage of GDP Methodology

I begin by getting a sense of the magnitude of investments required using a simple percentage of GDP methodology. The methodology uses historical investment trends identifying infrastructure spending as a percentage of GDP and projecting these into the future over a GDP growth rate assumption. Exhibit 1.3 presents these worldwide estimates on an annual basis over the next two decades.[6]

The estimates range from annual expenditure of approximately 3.5 percent of GDP between 2000 and 2010 to 2.44 percent between 2020 and 2030. The total annual expected demand for new infrastructure is around $6.8 trillion, with investment requirement of 0.66 percent of world GDP for electricity generation using traditional oil, gas, and coal investments. By 2030 investments required will be of the magnitude of $65 trillion, rising to $71 trillion if other energy-related investments are included in the estimates.

These massive investments are similar in magnitude to estimates developed using more complex models that explicitly incorporate different factors impacting demand. The International Energy Agency (IEA) estimates electricity demand using different fuel types based on increased capacity additions.[7] Exhibit 1.4 displays IEA estimates for electricity generation, transmission, and distribution to 2030.

The IEA uses a methodology that includes four major factors to estimate investments in energy infrastructure: GDP growth, population growth, energy prices, and technology. The methodology is delineated as follows.

1. *GDP growth.* The primary driver of energy demand is GDP growth. The IEA uses the income elasticity of demand (percentage change in energy demand for a 1 percent change in GDP) to estimate energy demand. Between 1971 and 1990 it was 0.66 percent, dropping to 0.44 percent in 1990–2000 and recovering to 0.68 percent in 2000–2006. A drop in energy intensity is likely to prevail, however, due to conservation efforts arising from the challenges of global warming and rising energy prices. The IEA uses International Monetary Fund (IMF) assumptions of economic growth, predicting that the GDP growth will recover to 4.5 percent per year by 2010 and then slow to an average of 3.3 percent per year to 2030. GDP growth is expected to average 4.2 percent per year in 2006–2015 and 2.8 percent per year in 2015–2030.
2. *Population growth.* Population as a driver of energy demand affects demand not only through overall population growth but also through the location of growth. Urban population growth increases energy demand significantly since most energy is consumed within or close to cities. The rapid urbanization of most countries in the developing world along with their higher growth rates affects the geographical distribution of energy demand.
3. *Energy prices.* Energy prices are an exogenous input in the IEA model, and price determines demand and supply of electricity. The oil price is assumed to average $100 per barrel in 2007 dollars till 2015, rising to $122 per barrel by 2030. The IEA assumes coal prices will settle at $120 per ton in real terms and then fall back to about $110 per ton by 2030. The IEA further assumes that gas prices linked to oil prices through indexation in long-term supply contracts or competition between end-users will remain at 60 to 70 percent of oil prices. The IEA model also considers policies by governments that reduce subsidies for energy since a large portion of the demand for energy comes from countries that subsidize energy.
4. *Technology.* The demand for energy from fossil fuels is very sensitive to the assumptions made about technology. The IEA does not assume any radical technological change. On the demand side it assumes that the efficiency of cars and trucks, heating and cooling equipment, boilers,

EXHIBIT 1.4 Estimated Annual Investment Demand in Electricity Generation, Transmission, and Distribution from 2007 to 2030

	Investment, 2007–2015 (2007 $ Billion)				Investment, 2016–2030 (2007 $ Billion)			
	Capacity Additions—MWs	Power Generation	Transmission	Distribution	Capacity Additions—MWs	Power Generation	Transmission	Distribution
OECD	514	$982.00	$278.00	$656.00	1,107	$2,467.00	$403.00	$922.00
North America	215	$379.00	$121.00	$260.00	480	$1,136.00	$238.00	$512.00
Europe	221	$457.00	$93.00	$281.00	465	$1,048.00	$94.00	$286.00
Pacific	78	$146.00	$65.00	$115.00	163	$283.00	$71.00	$124.00
Non-OECD	1,177	$1,215.00	$589.00	$1,285.00	1,730	$2,177.00	$837.00	$1,793.00
Eastern Europe/ Eurasia	137	$180.00	$55.00	$183.00	159	$274.00	$51.00	$173.00
Asia	781	$794.00	$433.00	$894.00	1,170	$1,379.00	$596.00	$1,231.00
China	574	$521.00	$296.00	$612.00	718	$753.00	$299.00	$618.00
Middle East	78	$59.00	$32.00	$67.00	160	$135.00	$71.00	$146.00
Africa	59	$59.00	$28.00	$58.00	91	$159.00	$47.00	$97.00
Latin America	121	$123.00	$41.00	$84.00	149	$230.00	$72.00	$148.00
World	1,691	$2,197.00	$867.00	$1,941.00	2,837	$4,644.00	$1,239.00	$2,716.00

Source: IEA, *World Energy Outlook* (OECD Publishing, 2008).

EXHIBIT 1.5 World Energy Demand by Fuel (Million Tonnes of Oil equivalent)

	1980	2000	2006	2015	2030	2006–2030*
Coal	1,788	2,295	3,053	4,023	4,908	2.00%
Oil	3,107	3,649	4,029	4,525	5,109	1.00%
Gas	1,235	2,088	2,407	2,903	3,670	1.80%
Nuclear	186	675	728	817	901	0.90%
Hydro	148	225	261	321	414	1.90%
Biomass and Waste	748	1,045	1,186	1,375	1,662	1.40%
Other Renewables	12	55	66	158	350.00	7.20%
Total	7,223	10,034	11,730	14,121	17,014	1.60%

Source: IEA, *World Energy Outlook* (OECD Publishing, 2008).
*Average annual rate of growth.

and so on, will improve. On the supply side the IEA assumes that efficiency of electricity generating plants, oil and gas exploration, and rates of recovery will increase with the availability of new technologies like carbon capture and storage, the conversion of coal to liquids, and the second generation of biofuels.

These projections are much higher than in the simple percentage of GDP method because they include the run-up in commodity prices and energy prices in 2007–2008. Higher prices of steel, copper, aluminum, cement, and other commodities significantly impact construction costs for electricity generation plants, fuel supply pipelines, transmission grids, distribution substations, transformers, metering equipment, and other costs. The estimates are also likely to vary with differing costs for land acquisition that are largely determined locally by country and in local regions within countries. Exhibit 1.5 summarizes demand for the different types of fuel.

Exhibit 1.5 reveals that although renewables are likely to record the fastest annual growth rate of 7.2 percent, they still make up only 2.05 percent of world energy demand by 2030. Coal grows fastest at 2 percent annually and constitutes 28.84 percent of world energy demand. Oil and gas make up 30.02 percent and 21.57 percent respectively by 2030. Should we consider investments in renewable energy as infrastructure investment? I visit this question in Chapter 2.

The next section deals with surface transportation infrastructure, primarily road and rail. These estimates are comparable to the percentage of

EXHIBIT 1.6 Estimated Annual Road and Rail Investment, 2000–2030 (US$ Billions)

	Road Construction Forecast			Rail Construction Forecast		
	2000–2010	**2010–2020**	**2020–2030**	**2000–2010**	**2010–2020**	**2020–2030**
OECD (Total)	159.5	167	178.2	31.1	34.2	33.5
North America	71.8	75.5	80.9	7.1	7.8	10.9
United States	62.4	65.6	69.3	5.2	6.3	8.8
Mexico	2	2.2	3.5	0.6	0.4	0.8
Europe	67.4	70.3	74.7	19.3	21.6	17.2
Germany	4.3	4.6	5.8	4	4.5	3.5
United Kingdom	5.8	6	6.1	1.8	2	1.6
France	13.2	13.7	14.3	2.6	2.9	2.3
Italy	7.1	7.4	7.8	2.7	3	2.6
All others	37	38.6	40.7	8.2	9.2	7.2
Pacific	20.3	21.2	22.6	4.7	4.8	5.4
Japan	13.5	14.2	15.1	3.2	3.4	3.7
All others	6.8	7	7.5	1.5	1.4	1.7
Non-OECD (Total)	52.3	68.6	101.1	15.7	16.7	21.3
Eastern Europe/Eurasia	12	15.9	20.5	3.4	3.7	4.2
Asia	15.8	18.6	25.4	2.6	2.9	5.4
China	15.2	23.8	37.8	7.3	8.1	7.7
Middle East	2.9	3.4	6.3	0.6	0.5	1.5
Africa	1.4	1.4	2.2	0.4	0.4	0.5
Latin America	4.8	5.6	8.9	1.4	1	2.1
World (Total)	211.8	235.6	279.3	46.8	50.9	54.8

Source: Infrastructure to 2030: Telecom, Land Transport, Water and Electricity (OECD Publishing, 2006); author analysis.

GDP methodology. Exhibit 1.6 shows annual estimated road and rail expenditure through 2030.

These estimates are derived from a model that the OECD developed, as follows:

- Road and rail demand are functions of growth in population and GDP per capita.

- The link between GDP per capita growth and road and rail demand is expressed in elasticity. A key measure used is elasticity of paved road capital stock with respect to GDP per capita. This elasticity measure has a range of 0.12 to 0.90 with a mean estimate of 0.20—in other words, a 1 percent increase in GDP per capita increases the paved road capital stock by about 0.20 percent. Similar measures for rail infrastructure are used but are not wholly reliable due to lack of sufficient data.

The model uses additional road infrastructure inputs like measures of road use and vehicle ownership. Demand for roads is proportional to increased vehicle ownership and increased road use. The study uses an elasticity of vehicle stock (measured in vehicles per 100 people) with respect to GDP per capita of 0.75 to 1.25 with a mean of 1.0, implying that a 1 percent increase in GDP per capita raises vehicle ownership by 1 percent. Since this relationship is nonlinear—once GDP per capita crosses $5,000, vehicle ownership accelerates—the model uses a step function. The model incorporates road use with elasticity of annual per-vehicle driving distance in kilometers with respect to GDP per capita, which has a range of 0.05 to 1.60, with a mean of 0.2. This implies that a 1 percent increase in GDP per capita raises road use by 0.2 percent.

Now that we have obtained a sense of the sectoral distribution of investments, we aggregate the data in terms of regions and country. This allows us to get a better sense of which sectors are important in which regions.

Geographical Distribution of Infrastructure Demand In order to compare the investment demand by geography we combine electricity, road, and rail investment forecasts. Exhibit 1.7 displays annual investment demand for electricity (generation, transmission, and distribution), road construction, and rail construction over the next two decades by geography. North America comprises the United States, Canada, and Mexico; Asia includes India and Indonesia; and Latin America includes Brazil.

Investments in electricity generation, transmission, and distribution dominate investments in road and rail. In terms of time periods, total annual electricity investments in 2010–2020 are shown as greater than investments in 2020–2030. However, annual investments in the North American electricity sector increase in the 2020–2030 period over the 2010–2020 periods, while Asian and Chinese electricity sectors slow down in 2020–2030. Total annual road transportation investments in 2020–2030 are higher than investments in 2010–2020. The geographical distribution of estimated

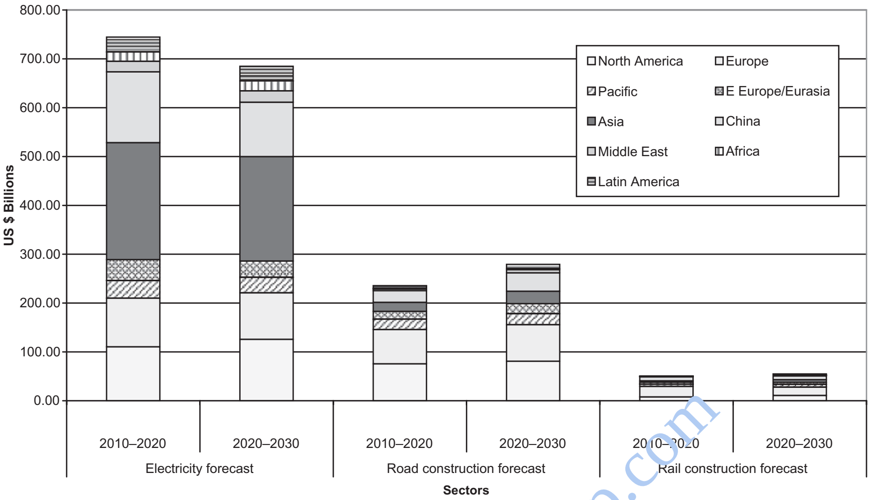

EXHIBIT 1.7 Annual Investment by Sector and Geography, 2010–2030
Source: *Infrastructure to 2030: Telecom, land transport, water and electricity. 2006* (OECD Publishing, 2006); IEA, *World Energy Outlook 2008*; author analysis.

investments is also instructive. Estimated demand in the electricity sector in Asia and China is larger than their demand for road and rail transportation. Estimated demand for road transportation in Europe and North America is larger than demand in Asia and China.

The OECD does not consider pipeline networks in its estimates. However, pipeline networks constitute highly efficient means of gas, oil, and petrochemical delivery and possess characteristics that classify them as infrastructure. Total pipeline density (kilometers per million people) also follows income growth and road and rail network distributions. I consider pipelines along with the other sectors in the methodology developed in the next section.

GNI Methodology

The second methodology uses income to estimate infrastructure demand. The World Bank classifies countries into low, middle, and high income countries in terms of gross national income (GNI) per capita and estimates that a per capita income of $5,000 is necessary before demand for services translates into revenues for suppliers of services. The methodology therefore

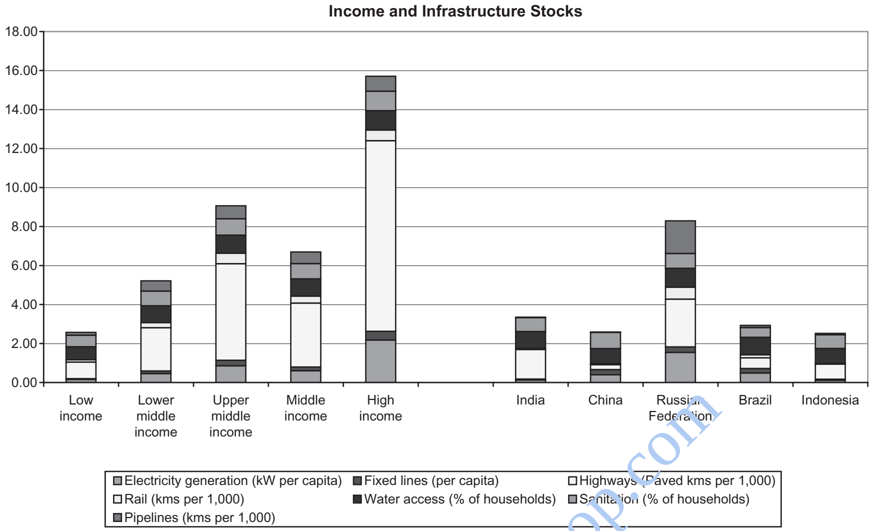

EXHIBIT 1.8 Gross National Income per Capita and Infrastructure Stocks

estimates demand in low- and middle income countries by extrapolating the present consumption of infrastructure services in the high income countries to middle and low income countries. Exhibit 1.8 presents the massive gap between infrastructure stocks in the high income countries and the middle income, low income, and the big five countries of Brazil, Russia, India, Indonesia, and China. Data sources are identified in the accompanying Exhibit 1.9.

Exhibit 1.8 immediately indicates the different relative rates at which infrastructure sectors are likely to grow in different countries. For example, a comparison between the big five countries shows that demand for electricity is likely to be higher in India, Indonesia, and China, while demand for roads is likely to be higher in China, Brazil, and Indonesia.

We can obtain a reasonable sense of the investment demand by comparing the level of infrastructure stocks present in the different income level countries. Comparing the upper middle income countries (GNI per capita between \$3,035 and \$9,386) and the high income countries shows that high income countries possess more than 2.5 times the electricity generating capability (in kilowatts per capita) and about twice the level of paved highways (in kilometers per 1,000 people) than upper middle income countries. Water and sanitation infrastructures are comparable. This suggests that the electricity and road sectors are likely to grow at a faster rate than water, sanitation, and railroads. In addition, the electricity sector is likely to grow

EXHIBIT 1.9 Income and Infrastructure Stocks

	GNI per capita	Population (Mils)	GDP per capita (PPP)	Electricity Generation (kW per capita)	Fixed lines (number per 1,000 people)	Highways (paved km per 1,000 people)	Rail (km per 1,000 people)	Water access (percent of households)	Sanitation (percent of households)	Pipelines (km per million people)
Low income countries	<$765	2,597.39	$1,840.16	0.16	36.71	0.85	0.12	0.66	0.59	148.45
Middle income countries	$765–$9,386	2,579.90	$8,543.77	0.60	188.66	3.28	0.36	0.88	0.78	597.94
a. Lower middle income	$765–$3,035	2,270.45	$5,911.06	0.46	130.20	2.22	0.27	0.86	0.76	524.65
b. Upper middle income	$3,035–$9,386	309.45	$12,736.60	0.85	288.66	4.95	0.54	0.92	0.84	666.92
High income countries	>$9,386	916.81	$29,745.71	2.18	448.24	9.77	0.55	0.99	1.00	769.43
Big Five										
India	$441.56	1,123.32	$3,113.10	0.13	45.45	1.52	0.06	0.86	0.72	16.93
China	$865.03	1,319.98	$5,453.31	0.39	268.63	0.25	0.06	0.77	0.83	25.61
Russian Federation	$1,764.05	141.64	$9,821.52	1.54	280.20	2.45	0.61	0.97	0.76	1,675.65
Brazil	$2,842.36	191.60	$7,967.52	0.49	230.45	0.55	0.16	0.90	0.50	113.20
Indonesia	$599.24	225.63	$3,222.33	0.11	57.91	0.78	0.03	0.77	0.70	74.76

Source: World Bank WDI indicators (GNI per capita, GDP per capita, population); NationMaster (www.nationmaster.com)—telecomm, road, rail, water, sanitation, and pipelines; U.S. Department of Energy—electricity generation capability; author analysis.

EXHIBIT 1.10 Unit Costs of Infrastructure Investments

Sector	Cost in US $	Unit
Electricity	$2,553	Per kilowatt of generating capacity, including associated network costs.
Roads	$551,006	Per kilometer of two-lane paved road.
Railway	$1,209,525	Per kilometer of rail, including rolling stock.
Sanitation	$941	Per connected household.
Water	$538	Per connected household.
Telecom fixed main lines	$538	Per line
Pipelines	$1,000,000	Per kilometer including right of way, labor, and materials

Source: Marianne Fay and Tito Lepes, “World Bank Policy Research Working Paper 3102 (July 2003), adjusted for inflation assumed at 3 percent per year from 2003.

faster than the road sector. We can use the differences in infrastructure stocks to generate individual countries’ investment demand by combining a country’s present infrastructure stock level, population, and unit costs for infrastructure. Exhibit 1.10 presents the unit costs for creating new infrastructure stock.[8]

Costs presented in Exhibit 1.10 will vary widely across countries because costs for building roads, rail, pipelines, and water and sanitation networks depend a great deal on terrain, weather, costs of obtaining licenses and permits, and labor and material costs. For example, electricity generation, transmission, and distribution costs have risen substantially with the rise in the prices of raw materials. These costs are therefore merely guides and we must interpret them with caution.

Exhibit 1.11 displays cumulative investment scenarios needed for electricity, paved highways, fixed telecomm lines, railways, water, sanitation, and pipelines for BRIC and Indonesia based on their present infrastructure stocks, and the difference between stocks in upper middle income countries and lower middle income countries.

The Russian Federation already possesses infrastructure stocks greater than upper middle income countries, and Exhibit 1.11 indicates investments needed to reach high income country levels. In order to calculate

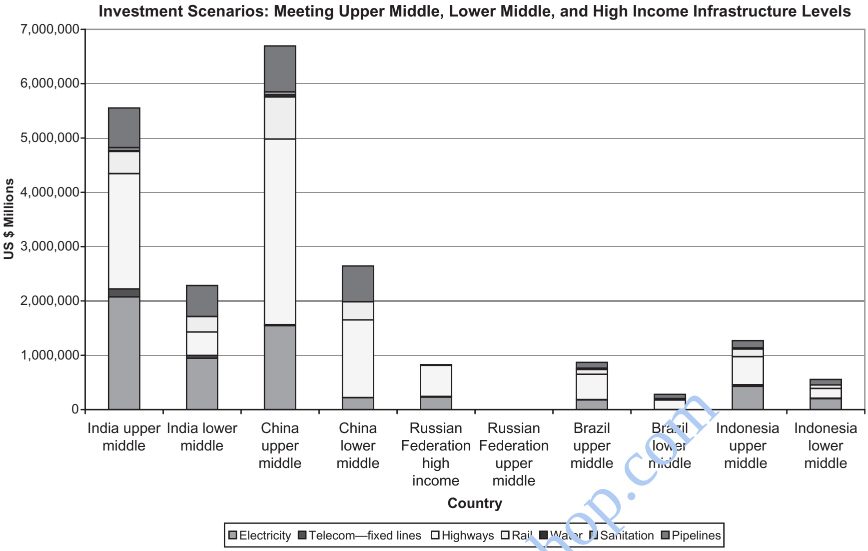

EXHIBIT 1.11 Cumulative Investments in Big Five Countries
Source: Author analysis.

water and sanitation investment data the unit of analysis is a household. The model therefore gathers data about the number of people per household. The average size of households in India is obtained from De Silva (2003).[9] The average size of households in Russia is obtained from the Russian Longitudinal Monitoring Study data at the University of North Carolina.[10] Data on average size of households in China, Brazil, and Indonesia comes from the *United Nations Demographic Yearbook*.[11] This provides the total number of households that need access to water and sanitation and the investments necessary. Exhibit 1.11 shows water and sanitation investments required to provide coverage for all households.

This methodology does not provide an indication of the time period over which these investments will be done. It assumes that the unit costs presented in Exhibit 1.10 and the size of households remain constant during this period. Costs, however, are likely to rise and the size of a household is dropping, which implies that these investments are underestimated.[12] Exhibit 1.11, however, shows which countries are likely to demand investments and which sector is likely to grow fastest in each country, assuming that government policies remain constant and are not altered to favor a particular sector (e.g., rail over road).

Conclusion

The discussion so far provides broad implications for targeting investments both geographically and in terms of infrastructural sectors. Developing countries with per capita GNI above $5,000, which places them in the lower middle income and upper middle income countries, are relatively more attractive destinations for investment. Electricity investments are likely to be more attractive, followed by road transportation, particularly in India and China, and to a lesser extent in Brazil, Russia, and Indonesia. OECD nations are likely to require relatively higher investments in road transportation than electricity. The discussion also highlights the fact that each country's individual policy environments are essential to developing an investment strategy, particularly with respect to favored mode of transportation, favored fuel for electricity generation, environmental policies, infrastructure tariffs, and so on.

Although Exhibit 1.11 shows investments for fixed telecom lines, an analysis of fixed telecom line demand is particularly difficult to predict. Although fixed telephone lines in high income countries are about 1.5 times those of upper middle income countries, predicting demand for fixed lines is difficult because of the adoption of mobile telephony as a substitute for fixed lines. The number of fixed lines in high income countries is actually declining (from 550.14 lines per 1,000 people in 2000 to 448.24 lines in 2007). Fixed-line networks might mimic the evolution of rail networks from 1960 to 2000 as mobile networks take their place.

What about the case for investing in mobile networks as a form of infrastructure? I do not consider mobile telephony to be an infrastructure sector because the impact of technology is difficult to predict. The development of a wireless wide area network (WWAN) utilizing WiMax or any of the numerous technologies in development now could disrupt an existing mobile network by providing users with Internet-based Voice over Internet Protocol (VoIP) telephony service that is virtually free.[13] WiMax is a wireless broadband technology standard that aims to provide fast wireless data connections over long distances, as opposed to Wi-Fi which provides fast wireless data connections over about 50 feet only. A consumer with a fast data connection can then transmit voice calls over the Internet using a slew of services available at almost no charge. As these technologies leapfrog over fixed lines and even mobile networks, investments in building fixed-line and mobile networks no longer possess infrastructure characteristics. I explore the topic further in Chapter 2.

AVAILABILITY OF FUNDS

Infrastructure has traditionally relied on public expenditure for financing. The enormous funding requirements we saw in the previous section imply that governments must consider the use of private capital to provide infrastructure services. Among private sources of capital, insurance companies traditionally provided the long-term funds needed for infrastructure.[14] Other private sources of capital include pension funds, mutual funds, petrodollars, hedge funds, private equity, endowments, and Asian central banks. Exhibit 1.12 displays the amount of capital these sources held in 2006.

Although the following discussion focuses on pension funds, insurance firms face similar asset allocation challenges and regulatory constraints. Infrastructure risks and their mitigation also apply equally well to all private capital, including insurance firms and private endowments. As Exhibit 1.12 shows, pension funds form the largest source of private capital that can meet the demand for investments at $21.6 trillion. Although pension funds

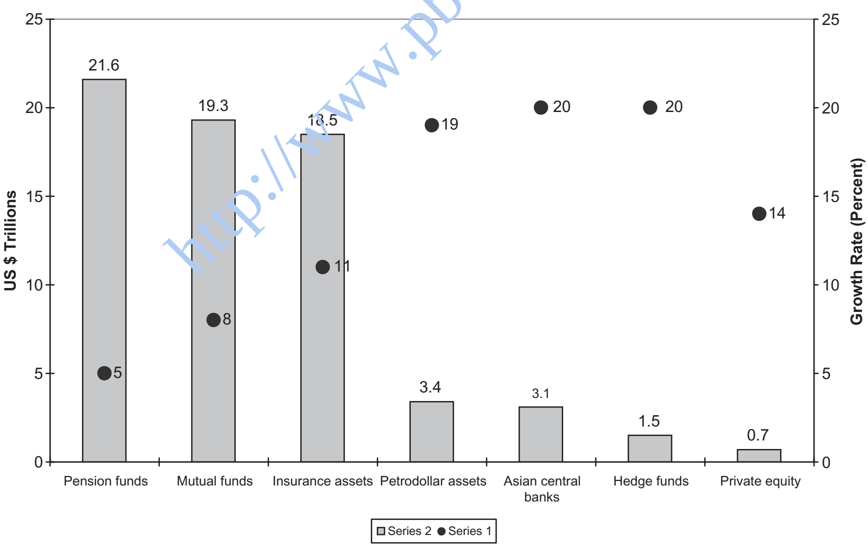

EXHIBIT 1.12 Assets under Management, 2006
Source: McKinsey Global Institute, *The New Power Brokers: How Oil, Asia, Hedge Funds, and Private Equity Are Shaping Global Capital Markets* (McKinsey Global Institute, October 2007).

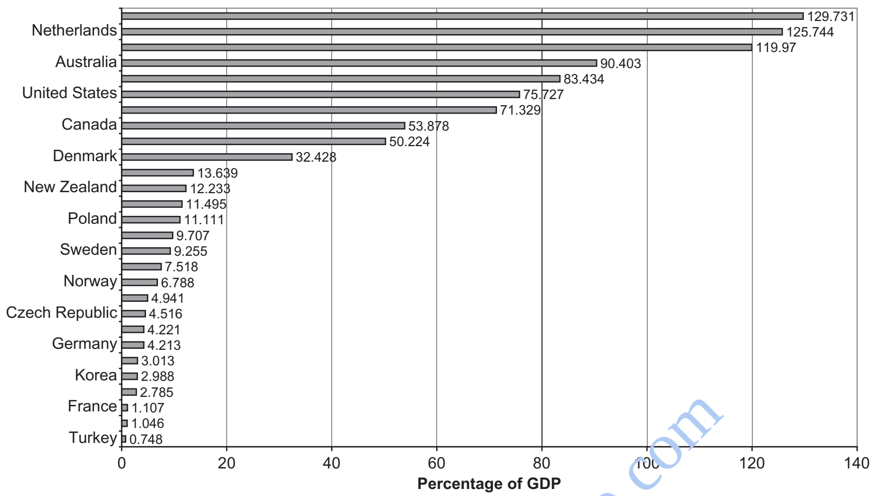

EXHIBIT 1.13 Pension Fund Assets: Percentage of GDP in 2006
Source: OECD Global Pension Statistics project; author analysis.

grew at 5 percent compound annual growth rate (CAGR) in 2000–2006 compared to 20 percent CAGR for hedge funds, pension funds possess a unique liability structure. I examine pension funds in greater detail in the following sections. Exhibit 1.13 shows details of pension fund assets for 2006 in different countries as a percentage of their GDP.

In Iceland, the Netherlands, and Switzerland, pension fund assets now exceed the total GDP of these countries while pension fund assets in Australia, the United Kingdom, and the United States constitute more than 75 percent of GDP. Pension funds therefore constitute a powerful source of capital that has altered asset markets worldwide. The next section examines present pension fund asset allocations and focuses on the duration of pension fund liabilities as one factor in their asset allocation decisions. Following that, I examine whether infrastructure meets pension fund objectives.

Pension Fund Asset Allocation

Private pension funds can be broadly categorized into *defined contribution* and *defined benefit* pension schemes along with many hybrid forms. A defined contribution fund pays its members their contribution with additional returns generated from their contributions, if any. A defined

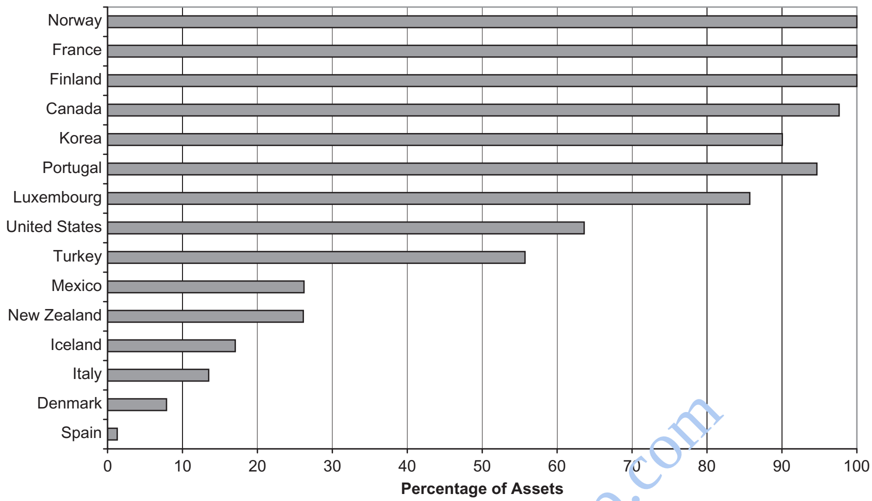

EXHIBIT 1.14 2007 Defined Benefit Pension Plans: Percentage of Total Pension Fund Assets
Source: OECD Global Pension Statistics project; author analysis.

benefit fund promises to pay its members retirement benefits at a certain level based on some formula that typically includes length of employment and member salaries. The fund must therefore have sufficient assets to meet its payment obligations. Typically, sponsoring employers establish a legally separate fund or hold in reserves separate funds to meet their future payment obligations. Worldwide, defined benefit funds form the vast majority of pension funds. Exhibit 1.14 shows percentage of defined benefit plan assets as a percentage of total pension plan assets in selected countries. U.S. pension plan assets dwarf other countries' pension plan assets at about $17 trillion, and defined benefit plan assets make up about 64 percent of all assets.

How have pension funds allocated their capital? Exhibit 1.15 provides details of assets under management in pension funds in 2005 for countries with the six largest funds other than the United States, namely the United Kingdom, Canada, the Netherlands, Australia, Switzerland, and Denmark.

Exhibit 1.16 shows total U.S. pension fund assets from 2001 to 2007 along with the asset classes to which funds are allocated.

Comparing Exhibits 1.15 and 1.16, we see that total assets under management (AUM) in the United States dwarf those in the United Kingdom,

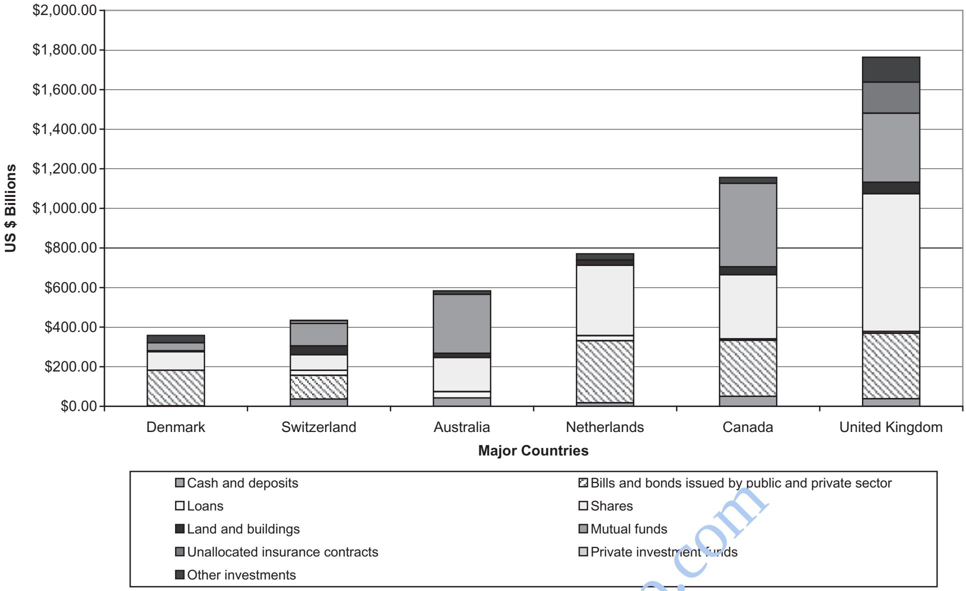

EXHIBIT 1.15 Pension Fund Asset Allocation, 2005
Source: OECD Global Pension Statistics project; author analysis.

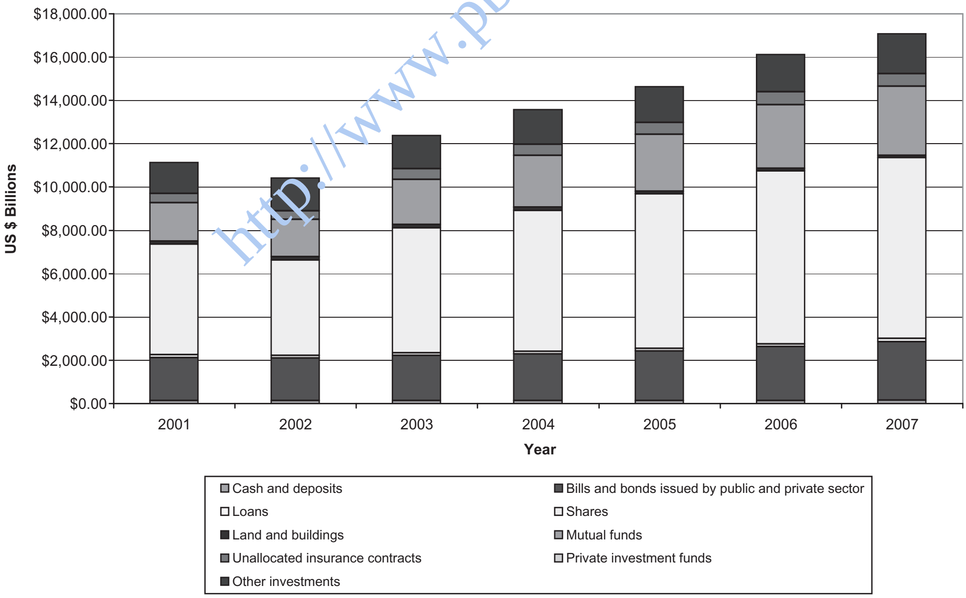

EXHIBIT 1.16 U.S. Pension Fund Asset Allocation, 2001–2007
Source: OECD Global Pension Statistics project; author analysis.

Canada, the Netherlands, Australia, Switzerland, and Denmark, with U.S. AUM in 2005 totaling almost three times the *combined* AUM for the largest six countries. Exhibits 1.15 and 1.16 also display asset allocation totals across asset classes. Except for Denmark, equities dominate the portfolios of pension funds invested either through mutual funds or direct holdings, with Australia at 80.4 percent, the United States at 66.63 percent, Canada at 64.47 percent, the United Kingdom at 59.2 percent, the Netherlands at 46.2 percent, and Switzerland at 44.41 percent. The drop in U.S. pension fund assets in 2002 likely reflects the dot-com bust and the decline in U.S. equity markets. We are likely to see a similar severe contraction in U.S. and other pension fund assets from the collapse in equity values in 2008–2009.

Fixed-income products through bills and bonds from both public and private issuers are the second largest holding. "Other investments" shown in the figures comprise investments in alternative asset classes like hedge funds, private equity, and commodities.

Pension funds have not been large participants in the infrastructure investment space. Funds allocated to infrastructure form a negligible portion of asset portfolios, although precise estimates are difficult without further granularity in the data. One problem relates to how infrastructure is classified. Infrastructure investments may be classified as equities if assets are allocated to firms engaged in infrastructure sectors, like AES or Fluor Corporation, or investments may be classified as bills and bonds, loans, or "other investments." For example, Australia and Canada have been pioneers in developing infrastructure investments. Australian pension funds allocated about 5.5 percent toward loans in 2005 that could be for infrastructure projects structured as project finance, where a large proportion of the capital is funded in the form of debt. Canadian pension funds allocated 24.43 percent to bills and bonds that may include bonds for infrastructure projects.

Pension Fund Asset Allocation Challenges

Pension funds are exposed to longevity risk, the risk of members living longer than benefits are planned for; and to financial risks, the risk that contributions from members and employers invested over long time horizons do not earn sufficient returns to meet fund obligations. If the estimated market value of a fund's assets falls below the value of its estimated liabilities, a funding gap exists. In 2002 and 2003, after the dot-com bubble burst, equity values fell while long-term interest rates also fell. A large proportion of pension fund assets invested in equities declined. Since long-term interest rates were used to calculate the value of liabilities, the value of liabilities rose, creating a funding gap.

A similar situation exists in 2008–2009. The enormous destruction of equity values has shrunk pension fund assets. The flight to safety of investments moving from equity markets to government securities, along with central banks lowering interest rates, resulted in historically low long-term interest rates. The resulting rise in the value of pension fund liabilities creates significant funding gaps in defined benefit pension plans. This funding gap has resulted in a sharper focus on risk management through closer asset-liability matching.[15]

The OECD's guidelines on pension fund asset allocation[16] require a fund's retirement income objectives to be taken into account before making asset allocation decisions. The guidelines recommend risk management processes for each fund's assets and liabilities and recommend a level of asset-liability matching that the pension fund's governing body can monitor. Interestingly, the guidelines do identify prudent quantitative limits for exposure to a single security or issuer but consider limitations on foreign investment and broad asset classes like equities and bonds as potentially constraining portfolio efficiency. The requirement of asset-liability matching increases with the dollar value of pensions in payment and in proportion to the number of pensioners. The looming retirement of U.S. baby boomers, along with changing demographics relating to the increase in expected life span after retirement, is almost certainly going to increase the proportion of pensioners in these countries' pension funds.[17] Although detailed data about pension fund liabilities is not available, most estimates put the duration of pension fund liabilities at around 15 years.[18]

The requirement of pension funds to match long-duration liabilities leads to a demand for long-duration assets with predictable cash flows. Defined benefit plans must particularly match cash flows from assets to meet promised payments to pensioners. Thompson (2003) points out there aren't sufficient assets for pension funds to implement a policy of asset-liability matching.[19] In fact, if pension funds shifted parts of their portfolio holdings to long-term bonds as a source of long-duration assets with predictable cash flows, there would be a scarcity of bonds.[20] Erwin and Schich (2007) compare future pension fund payment promises with the cash flows obtained from investing in government bonds in the G10 countries. Exhibit 1.17 shows the cash flow shortfall that pension funds would experience from 2012 onwards based on the level of funds allocated to government bonds.

An additional assumption underlying Exhibit 1.17 is that pension funds do not incur new liabilities and the payments are all made to *passive*

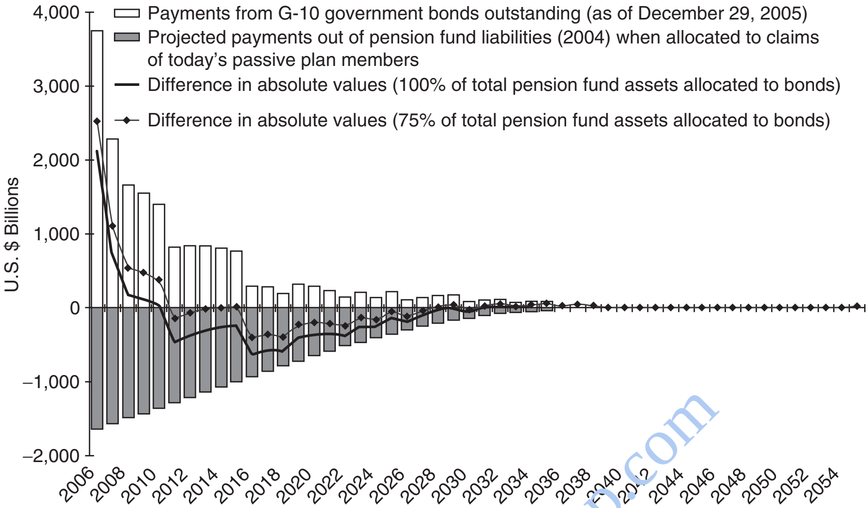

EXHIBIT 1.17 Difference between Government Bond Cash Flows and Projected Pension Payments in G 10 Countries
Source: C. Ervin and S. Schich, "Asset Allocation Challenges for Pension Funds, *Financial Market Trends* 1, no. 92 OECD, (2007): 129–147.

plan members. Passive plan members are members that do not contribute to the pension plan. It is likely that pension funds actually do incur new liabilities with the increase in retirees, which also leads to an increase in the number of passive members. Given the scarcity in long-term government bonds and other long-duration assets with predictable cash flows, can infrastructure fill this gap? Infrastructure investments till 2030 are estimated at $71 trillion. These investments will generate cash flows over the time horizon that pension fund obligations come due. Some experts have argued that pension fund liabilities are a better match for equities because of their longer tenor and because equities outperform bonds over the long term. Clearly, large portions of pension fund portfolios must be made up of equities.

In the following chapters I examine whether infrastructure investments provide the benefits of a separate asset class. and whether equities of firms in infrastructure sectors actually diversify an equity portfolio. Extending the analysis of investment form, I examine the risks from the private equity model of infrastructure investment, specifically whether it increases investors' exposure to political risk without commensurate returns.

CONCLUSION

Of the estimated $21 trillion in pension fund assets, almost $2 trillion would be immediately available for infrastructure investments if a mere 10 percent is allocated to infrastructure. Although these investments are insufficient to satisfy worldwide total infrastructure demand, they can meet a large portion of demand from upper middle income countries and the big five countries. These countries are most attractive from the perspective of revenues from subscriber fees. Countries differ in the investments needed in different sectors as shown. Countries also differ in infrastructure policies of regulation, pricing, and permits, and in the sectoral industry structures. Countrywide and sectoral analysis is therefore a necessary component of infrastructure investing, and it makes sense for investors to develop sectoral as well as geographical expertise before allocating capital.

Chapters 2 through 8 analyze infrastructure characteristics and develop the case for the precise form of investment.