CHAPTER 6

The Transportation Sector: Energy and Infrastructure Use

Energy is a $1 trillion industry representing 8 percent of the U.S. economy. The two biggest consumers of energy from fossil and renewable fuels are electric power and transportation. While electricity can be generated from diverse sources—coal, nuclear fission, natural gas, water, petroleum, and increasingly, wind and sun—98 percent of transportation, whether by plane, train, ship or automobile, is currently powered by petroleum. The transportation sector alone accounts for two-thirds of the petroleum consumed in the United States. Thus, key to understanding the transportation sector is understanding the petroleum market, and the ways in which consumers and firms in the transportation sector respond to changes in world oil prices.

The lack of substitutes for oil means that in the short run, oil consumption in transportation is particularly unresponsive to price changes. This makes the economy vulnerable to sudden increases in oil prices. Perhaps more importantly, the world's reliance on oil creates an external cost in terms of national security.

In addition to petroleum, the transportation sector relies on infrastructure. The United States has close to 4 million miles of roads, bridges, and highways to support a wide variety of economic and social activity. Over time, however, demands on this infrastructure have outstripped its capacity. While the miles of urban roadways built have increased by nearly 60 percent since 1980, vehicle miles traveled on urban roadways increased by double that amount. The primary reason for this shortfall is that a well-functioning market that puts a price on roadway use is largely nonexistent. As a result, traffic in most metropolitan areas has become increasingly congested, costing both time and fuel. In 2003 alone, Americans were delayed about 3.7 billion hours and used 2.3 billion extra gallons of fuel (47 hours and 29 gallons per rush-hour commuter) in stop-and-go traffic. Like the costs exacted by oil use on national security and the environment, the full costs of congestion are not taken into account by individuals when they drive: each driver usually decides when and where to drive based on his or her own private needs and ignores the costs imposed on others.

This chapter discusses several developments in the use of energy and infrastructure for transportation, and reviews strategies that have been used to reduce oil use and better manage the existing infrastructure. Key points in this chapter are:

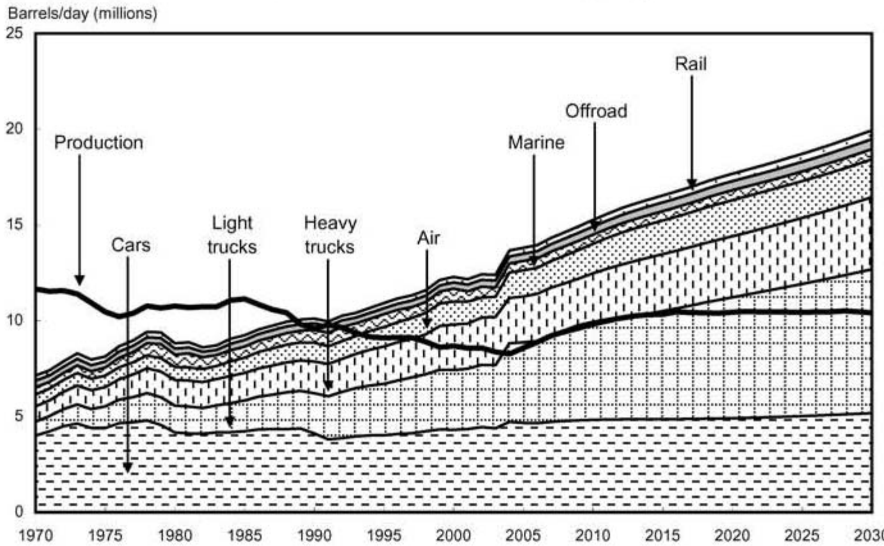
- Recent increases in the price of oil and the external costs of oil have led to renewed interest by markets and governments in the development of new alternatives. Government can play a role in ensuring that external costs are taken into account by markets, but ultimately markets are best suited to decide how to respond.
- Cars and light trucks are the largest users of petroleum. As a result, the fuel economy of the vehicles purchased and the number of miles that they are driven have a large effect on oil consumption.
- Congestion is a growing problem in American urban areas. Cities and states have shown a growing interest in and capacity for setting prices for road use during peak periods to reduce the full economic costs of congestion.

Fuel Markets and the Transportation Sector

Over the past 15 years, petroleum use in the industrial, utility, and building sectors has been relatively flat, while petroleum use by the transportation sector has grown by 27 percent. This trend is expected to continue. While new, more energy-efficient technology has reduced the energy needs of most sectors, gains in vehicle engine efficiency have been more than offset by a shift to heavier, more powerful cars and light trucks, and increases in driving.

Cars and light trucks accounted for 92 percent of U.S. roadway travel in 2006 and account for 62 percent of petroleum devoted to transport. Department of Energy projections suggest that these modes of transportation will continue to be important, and that light truck usage will show significant growth in the years to come (see Chart 6-1). Heavy trucks consume almost 17 percent of the petroleum used for transport. Air, rail, marine, and off-road vehicles currently account for the remaining 21 percent. Air travel is one of the fastest growing modes of transportation. Energy consumption for air travel is projected to increase nearly 46 percent by 2030, or about 620,000 more barrels of oil per day.

Chart 6-1 **Historical and Projected U.S Oil Consumption and Production**
Growth in petroleum use is projected to continue unabated in the foreseeable future. Cars and light trucks make up the bulk of U.S. oil use, while air oil use is one of the fastest growing.



Note: The sharp increase in values between 2003 and 2004 is due to the change from historical to projected values.
Source: Department of Energy (Oak Ridge National Laboratory and Energy Information Administration).

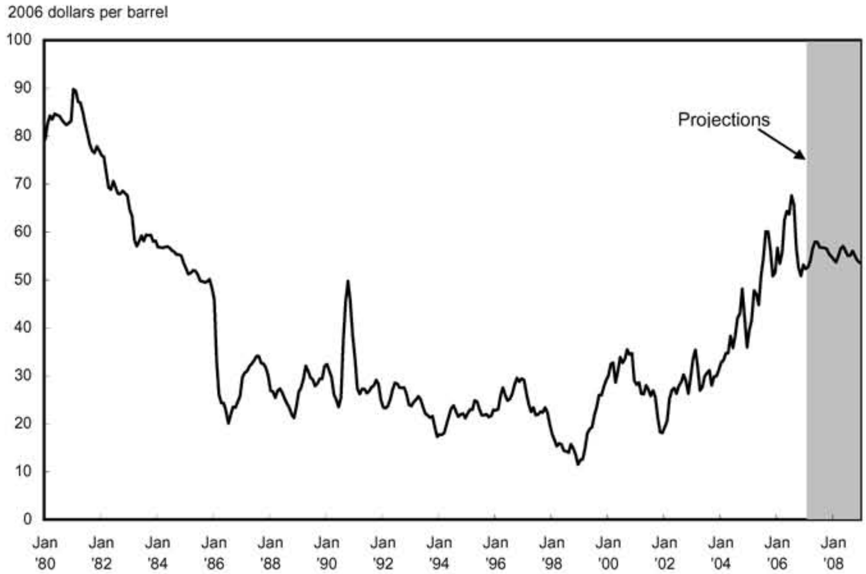
Responding to Changes in the Price of Oil

In well-functioning markets, the price of a good or service reflects all of the associated costs and benefits—for example, the costs incurred in extracting, transporting, and refining the oil, or the benefits from using gasoline to drive. The market then uses price to achieve the most efficient level of production and consumption. Transportation has largely reacted to changes in energy markets in this way.

High demand for oil, due in part to rapid economic growth in China and India, has helped push oil prices to record levels. The real average monthly price of oil to the refiner was $26 between 1986 and 2004 (see Chart 6-2, in 2006 U.S. dollars). In 2004, the price to the refiner began to climb, approaching $70 per barrel in 2006 (other oil price measures were higher). For the transportation sector, this is a significant increase in the cost of one of its primary inputs. Normally, as the price of a good rises, consumers reduce how much they use. However, it typically takes years before the transportation sector's consumption of oil is substantially reduced, in part due to the lack of easily available substitutes. Eventually, though, consumers do react to high prices. For instance, hybrid vehicle sales have tripled since 2004, while light truck sales have fallen by 16 percent.

Chart 6-2 **The Real Price of Imported Crude Oil**

Oil prices fluctuate over time, but current prices are above the historical average.



Note: Imported Refiner Acquisition Cost (RAC) Crude Oil.
Source: Department of Energy (Energy Information Administration) .

When high oil prices are sustained, as has been the case recently, the market shows renewed interest in investing in new technologies for developing alternatives to oil and improving vehicle fuel economy. Such research and development investments tend to recede when oil prices fall. During the period of high oil prices in the late 1970s and early 1980s, the private sector invested billions of dollars in energy research and development before the price of oil declined. A recent study finds that private investment in alternative fuel technologies again has increased in response to higher oil prices, doubling between 2004 and 2006, constituting 10 percent of the total investment in energy. Because of the transportation sector's delayed response to oil prices, these increases are likely to continue for some time.

The lack of alternatives to oil also means that sudden major oil supply changes—such as when oil production in an entire region is unexpectedly shut down—can lead to large and sudden price increases in the months following the shock. Since oil trades in a global market, the impact on the economy from such shocks does not depend on how much we import, only on how much we consume, and our consumption has been growing. The market has adapted to this threat by investing in more energy-efficient modes of production, investing in alternative energy sources, and increasing holdings of private oil inventories.

External Costs of Oil Use

Prices determine which goods and services are produced in the marketplace. In the absence of government policy (such as taxes or regulations), the price of a good or service accounts for all private costs incurred by those who have produced or purchased the product. In the case of oil, this includes everyone from the oil company that extracts the oil, to the shipper, refiner, retailer, and driver who fuels her car. In the case of oil, the price reflects most of the costs, but there are some costs to society that remain unaccounted for.

Eighty-one percent of the world's remaining proven petroleum reserves are currently controlled by members of the Organization of Petroleum Exporting Countries (OPEC) (including Iran and Venezuela) and Russia, and nearly all of these reserves are controlled by national oil firms. Since oil trades in a world market, oil consumption anywhere in the world affects the price of oil for Americans. The importance of oil to the world economy gives the major oil-producing countries disproportionate diplomatic leverage in world affairs. Oil resources can also fuel corruption in developing countries. Air pollutants and carbon dioxide from burning gasoline also contribute to concerns about air quality, human health, and climate.

The purchase of a gallon of gasoline imposes these national security and environmental costs on everyone, not just on the buyer and seller. Though State and Federal gasoline and diesel fuel taxes and regulations help account for these other costs, many studies suggest that the total external costs of oil may be higher. Carefully crafted government policy may be a useful way to account for these additional costs. However, this objective should be balanced against additional inefficiencies that government involvement introduces into the market. Once policies are in place that ensure that individuals account for the full costs of the goods and services they consume—e.g., national security and environmental concerns—competitive markets are the most efficient means to determine how goods are produced, as well as which goods are produced in the future.

Transportation Fuel Supply

Motor gasoline and diesel fuel will continue to be the main sources of power for cars and trucks in the near future. In 2006, motor gasoline accounted for 74 percent of fuel used in highway vehicles, and diesel accounted for 24 percent (alternative fuels made up the remainder). Diesel cars and light trucks are uncommon in the United States—only 2 percent of new cars and light trucks sold use diesel engines; the majority of diesel fuel is used by commercial vehicles.

Ethanol, an alternative fuel, is currently used as an additive in gasoline to increase octane and help gasoline burn more completely, reducing emissions of carbon monoxide and other pollutants. In many states and metropolitan areas, gasoline sold at the pump contains between 2 and 10 percent ethanol, depending on State requirements. Using such alternatives to oil can reduce the environmental costs of transportation as well as the national security consequences of oil use. To further encourage alternative fuel use, a provision in the Energy Policy Act of 2005 (EPAct 2005) known as the Renewable Fuel Standard requires a certain quantity of renewable fuel to be used by gasoline producers each year. In 2006, producers were obligated to use 4 billion gallons per year; this obligation will gradually increase to 7.5 billion gallons in 2012 (Americans consumed about 140 billion gallons of motor gasoline in 2006). One of the strengths of this policy is that it does not choose which renewable fuel to promote, but allows the standard to be met with any renewable fuel that accomplishes the goal of reducing oil use. However, it does not extend to oil alternatives beyond renewable fuels, such as electric cars or hydrogen fuel cells. The Renewable Fuel Standard also allows imports to satisfy the standard, allowing U.S. consumers to take advantage of cheaper production of renewable fuels in other countries, although this is impeded by an import tariff on such fuels.

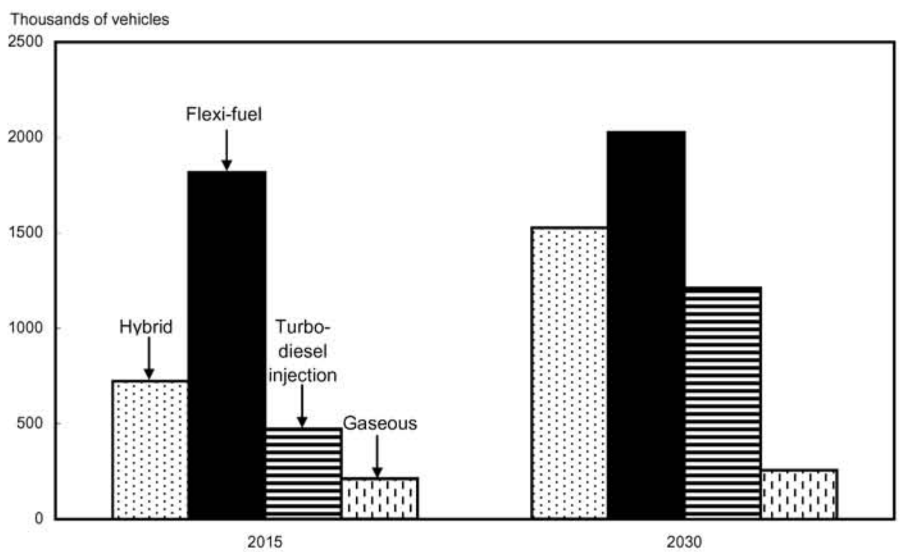
A more significant regulatory change has been applied to diesel fuel. Starting in 2006, diesel fuel sold in the United States is required to have a sulfur content of no more than 15 parts per million (ppm), down from 500 ppm in the previous standard. This reduction results in the most stringent diesel fuel standard in the world and enables U.S. consumers to purchase vehicles with engines that meet clean air requirements using clean diesel fuel. Diesel engines are between 20 and 25 percent more fuel efficient than comparable gasoline engines (even accounting for the fact that a gallon of diesel contains more energy than a gallon of gasoline). EPAct 2005 also grants tax credits to buyers of diesel cars that meet stringent emission standards.

Alternative Fuels and Advanced Technologies

To date, changes in petroleum usage have been driven primarily by the increasing price of oil and by regulatory concerns. The greatest potential for large reductions in gasoline consumption stems from new technologies that could transform how transportation is powered. Over 1 million advanced technology cars and light trucks were sold in the United States in 2006. About two-fifths of these were flex-fuel vehicles that can use conventional gasoline or an alternative fuel called E85, which is approximately 85 percent ethanol and 15 percent gasoline. U.S. consumers also purchased 256,000 hybrid vehicles in 2006. Hybrid vehicles use an electric motor in conjunction with a gasoline engine to increase fuel economy.

Use of advanced technology vehicles in the United States is projected to grow over time (see Chart 6-3). The Department of Energy projects that over 3 million advanced technology vehicles will be sold in 2015 and that by 2030 they will make up more than 25 percent of all light-duty vehicles sold. Of these advanced technology vehicles, 71 percent are expected to be either gasoline–electric hybrids or vehicles that can be powered by ethanol and other plant-based fuels. Though alternative fuels currently power only a small fraction of our transportation needs, private-sector investments combined with government policies are expected to fundamentally change the energy landscape.

Chart 6-3 **Projected Sales of Alternative Technology Cars and Light Trucks by Fuel Type**
Alternative technology vehicles are projected to increasingly displace conventional oil-using vehicles in upcoming years.



Note: Sales from fuel cell and electric cars are relatively small.
Source: Department of Energy (Energy Information Administration).

Ongoing research explores a wide variety of vehicle fuel technologies such as electricity, hydrogen fuel cells, and biofuels. Significant technological barriers exist that prevent the development of these as commercially viable alternatives. For instance, the wide-scale deployment of hydrogen fuel cells—devices that combine hydrogen with oxygen in the atmosphere to yield electricity—will depend on reductions in expense and weight as well as on the development of clean, cost-effective sources of hydrogen.

Private markets tend to underinvest in innovation of all kinds because inventors only capture a fraction of the benefits from discovery. Underinvestment is particularly likely for basic scientific research where the application to the marketplace may not be evident at early stages. Underinvestment is also likely when the results of research mainly reduce the external costs of consumption (such as national security and environmental costs associated with oil) instead of directly benefiting consumers. In response, the President's Advanced Energy Initiative proposed an increase in annual funding for alternative energy research of 22 percent for fiscal year 2007, adding to the $10 billion of government spending devoted to such research since 2001.

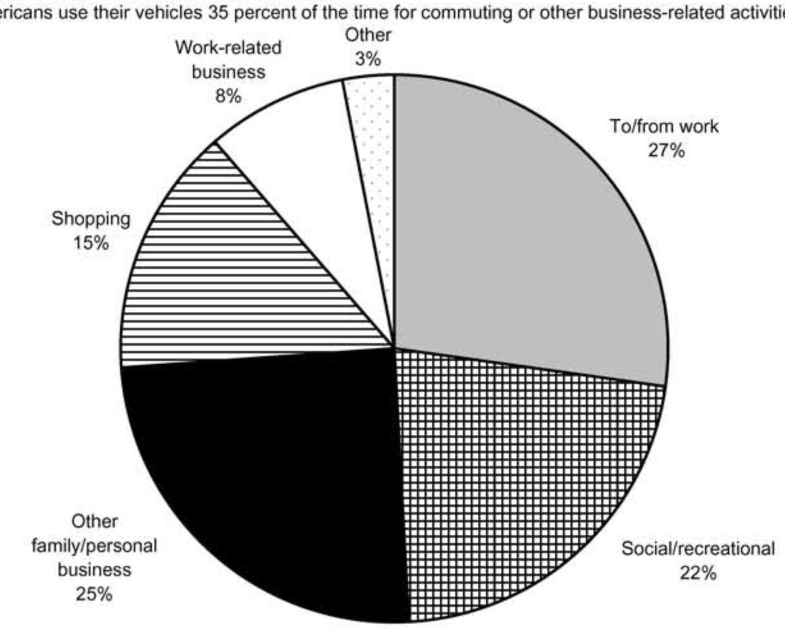
Several studies find that Federal research and development (R&D) investment in energy has yielded sizeable societal benefits, not only in economic terms, but also in terms of knowledge creation and pollution reduction. Still, the government's ability to predict which technologies will best meet a given goal is questionable, so the most effective government policies allow the market to choose the path of innovation.

Demand for Transportation Fuel

The United States is a vehicle-dependent society. More than 9 out of 10 American households own at least one vehicle, and most households own two. In 2004, vehicles in the United States traveled close to 3 trillion miles, up more than 20 percent from 1995. Commuting and other business-related activities account for about 35 percent of vehicle miles traveled (see Chart 6-4). Americans also use their cars and trucks to go shopping (15 percent of miles driven), attend to personal and family business such as medical appointments and dropping children off at school (25 percent of miles driven), and for social and recreational activities, including vacations (22 percent of miles driven).

Chart 6-4 **Share of Vehicle Miles Traveled**

Americans use their vehicles 35 percent of the time for commuting or other business-related activities.



Source: Department of Transportation.

In spite of widespread vehicle use, the proportion of the American household budget spent on transport fuel is small (less than 4 percent). That said, Chart 6-4 shows that a significant share of vehicle miles traveled are related to nonwork activities, indicating that households may have some flexibility to quickly adjust when the costs of travel are high. In response to higher prices, drivers make two adjustments: they drive less and they purchase more fuel-efficient vehicles. Several studies have found that these two effects combined imply that a 10 percent increase in the price of gasoline will result in about a 4 percent decrease in gasoline consumption in the long run. Compared to other commodities, households' gasoline consumption may take several years to respond to price changes.

State and local initiatives that encourage use of mass transit and carpooling focus on encouraging people to drive less. In New York City, the most densely populated of all cities in the United States, mass transit accounts for 45 percent of all commutes into the central city. New York, however, is unique. Many U.S. cities, such as Phoenix and Los Angeles, are spread out over a large area, making it difficult to design mass transit corridors that effectively meet the commuting needs of travelers. Public transportation also has difficulty competing with the flexibility and convenience of car travel in these types of cities. In the entire United States, 5 percent of commuters rely on public transportation.

One way many urban areas try to encourage carpooling is through the designation of high-occupancy vehicle (HOV) lanes. This method rewards carpooling by allowing vehicles with two or more passengers to travel in lanes not open to vehicles with only one person in them. In this way, HOV drivers can reduce travel time when roads are congested. Unfortunately, HOV lanes are often underutilized and the popularity of carpooling is not increasing. In 2000, 90 percent of American commuters drove to work each day, but of these drivers only about 13 percent carpooled, down from almost 20 percent in 1980. This trend makes it unlikely that initiatives focused on carpooling will make large strides in reducing vehicle fuel use.

Improving Fuel Economy

Evidence shows that drivers switch to more fuel-efficient vehicles in response to higher gasoline prices. One study finds that higher gasoline prices accelerate the retirement of older, less fuel-efficient vehicles, and shift new purchases toward more fuel-efficient vehicles. Government policies have also been used to influence vehicle fuel economy. The Corporate Average Fuel Economy (CAFE) standard, passed in 1975, mandates a minimum mile per gallon (mpg) requirement for each manufacturer's fleet of new cars and a minimum requirement for each manufacturer's fleet of new light trucks. If a given vehicle is less fuel efficient than the requirement, the manufacturer must offset it by producing a vehicle that is more fuel efficient, so that the average fuel economy for all cars (or for all trucks) the manufacturer sells is above the required miles per gallon level. One rationale used to justify increasing the stringency of the CAFE standard is to further induce improvements in the fuel economy of vehicles sold to consumers, reducing the demand for transport fuel and the external costs associated with oil use.

It is important to note that while improvements in fuel economy translate into gasoline savings, it is not a one-to-one relationship. Higher CAFE standards encourage increased driving. Since higher fuel economy vehicles can go the same distance using less gasoline, the cost of driving a mile is reduced. As the per-mile cost of driving declines, the quantity of miles driven by individuals tends to increase. This "rebound effect" reduces potential fuel savings from improvements in fuel economy by 10 to 30 percent. Recent estimates suggest that as incomes grow, driving decisions will depend less on the cost of driving, and therefore, the rebound effect is expected to shrink in the future.

In 1978, CAFE mandated 18 mpg for cars and 17.2 mpg for light trucks. The CAFE standard became increasingly stringent until 1990, after which it remained virtually unchanged. It only recently became more stringent for light trucks. Currently, the CAFE standards are 27.5 mpg for cars and 22.2 mpg for light trucks (including SUVs). The Federal government has increased the CAFE standard for light trucks through two separate regulations, raising it in increments each year beginning in 2005. By 2011, new light trucks will meet a 24 mpg standard, reflecting a 16-percent increase. Also by 2011, the largest SUVs—those weighing between 8,500 and 10,000 pounds—will be subject to the CAFE standard for the first time. The Department of Transportation based the new standard for light trucks on vehicle footprint, a measure of size, in line with a recommendation by a National Academy of Sciences panel as a way to mitigate safety concerns. The footprint-based CAFE standard for light trucks is also an improvement over its previous configuration because it ensures that all manufacturers make fuel economy improvements instead of only those producing a wide mix of vehicles. The Department of Transportation is seeking similar authority to reexamine CAFE for new passenger cars (see Box 6-1).

The fuel economy of new vehicles rapidly increased over the first 8 years of CAFE. In part, this was a market response to the dramatic increase in gasoline prices between 1973 and 1981. By the late 1980s, however, overall fuel economy had stagnated. While the fuel economy of cars has continued to slowly increase over time and has been above the CAFE standard since 1986, consumers have bought an increasing number of SUVs and light trucks whose fuel economy has remained close to the mandated level of the light truck standard. Half of all vehicles sold in 2005 were light trucks, including SUVs, compared to 20 percent when CAFE was first put in place. This shift in consumer preferences is a rational response to more than a decade of low real gasoline prices, rising household incomes, and incentives created by CAFE requirements. Manufacturers also responded to changing consumer preferences and CAFE requirements. For instance, while station wagons and minivans have similar fuel economies, the former are counted as cars, and the latter are counted as light trucks. In the late 1980s, many manufacturers took advantage of the difference in the stringency of CAFE standards across cars and light trucks to phase out the station wagon—a relatively fuel-inefficient car—and replace it with the minivan—a relatively fuel-efficient light truck. This shift improved the individual fuel economy of both the car and light truck fleets but did little to change overall fuel economy. While the CAFE standard has contributed to improved fuel economy since its inception, understanding its precise impacts and its interaction with gasoline prices is a matter of some debate. A recent National Academy of Sciences study also finds that CAFE may have led manufacturers to produce smaller and lighter cars, posing a risk to safety.

Box 6-1: The President's New Energy Initiatives

The President has announced several energy initiatives designed to increase the country's energy security by reducing projected gasoline consumption in the light-duty vehicle transportation sector by 20 percent within a decade.

About three-fourths of this goal will be met by greatly increasing and expanding the Renewable Fuel Standard. The new standard will mandate that 15 percent of transportation fuels come from alternative fuels. In 2006 about 3 percent of fuels used in light-duty vehicles were not petroleum-based. Under the revised standard 35 billion gallons will be alternative fuels in 2017. This initiative reflects the belief that technological change is the key ingredient to diversifying America's energy portfolio. Energy security will increase as the dominance of oil use in the transportation sector diminishes.

The standard will continue to allow refiners, importers and blenders to use renewable fuels to meet the standard but will expand to allow for current or future viable alternatives to petroleum to compete. Expanding the alternatives that meet the standard makes it easier for blenders and refiners to comply and affords the market broad flexibility to find the most cost-effective non-petroleum-based fuel options. In the event that production of alternative fuels proves more costly than expected, the President has built in two safety valves to protect consumers. First, the Administrator of the Environmental Protection Agency, and the Secretaries of the Department of Energy and the Department of Agriculture will have the authority to waive or modify the standard if refiners and blenders have difficulty finding alternative fuels for purchase. Second, an automatic mechanism will be in place to prevent the price of gasoline from rising above a threshold due to this policy. These two provisions ensure a degree of market stability as use of alternative fuels expands in the marketplace.

The 20 percent goal will also be met through increasing the fuel efficiency of automobiles. This will occur through reforming and modernizing CAFE standards for cars and further increasing light truck and SUV standards. These changes are predicted to reduce consumption of gasoline by an estimated 5 percent, based on the assumption that increases in the standard of 4 percent each year starting in 2010 for cars and 2012 for light trucks prove warranted. Three reforms are key to the President's proposal of increased stringency of CAFE. First, paralleling recent changes for light trucks, the law for cars should be changed to allow the standard to be based on a vehicle attribute (such as footprint) to address safety concerns. Second, CAFE for both cars and light trucks should allow manufacturers the option of increased flexibility in how they meet the standard, by allowing them to trade credits. Any manufacturer that increases fuel economy by more than what is mandated could generate credits that other manufacturers could purchase to reduce their costs of meeting the standard. The benefit of trading credits is that it allows the same overall goal of improved fuel economy to be met at a lower cost. Third, the rate of increase of the CAFE standard as well as how fuel economy improvements will be divided between cars and light trucks should be at the discretion of the Secretary of Transportation, as is currently done for light trucks. The Department of Transportation will employ the regulatory process to determine these increases based on sound science and an assessment that balances the costs and benefits.

The President has also proposed a new $175 million initiative to give State and local governments the opportunity to explore innovative ways—such as roadway pricing and increased use of real-time traffic information—to reduce traffic congestion and save fuel.

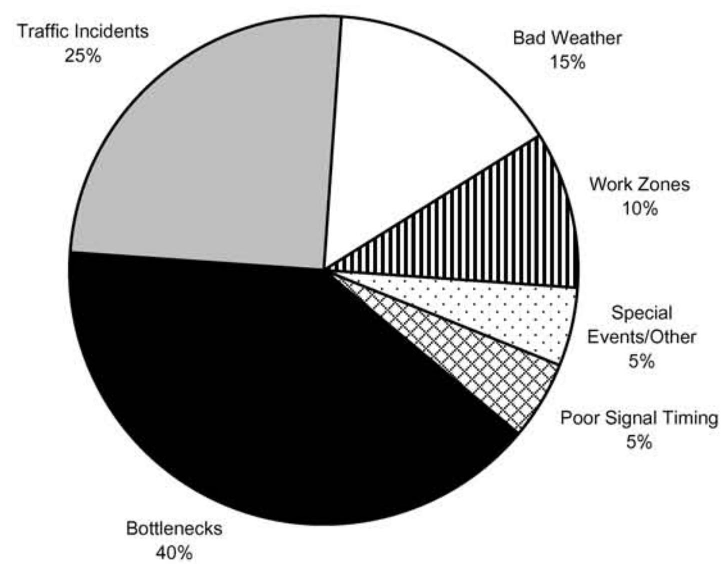
In addition to improving the nation's energy security profile, these initiatives will also produce significant benefits by reducing air toxics associated with petroleum-based fuel. They will also help confront the challenge of climate change by potentially stopping the projected growth of carbon dioxide emissions from this sector.

Transportation Infrastructure and Management of Existing Traffic Flow

In addition to its reliance on oil, the transportation sector also relies heavily on the existing infrastructure of roads and highways. Under the Intermodal Surface Transportation Efficiency Act of 1991, the Federal government plays an important role as overseer of the National Highway System to ensure that the highway system is "economically efficient and environmentally sound, provides the foundation for the Nation to compete in the global economy, and will move people and goods in an energy-efficient manner." In recent years, however, the road and highway infrastructure has not kept pace with the number of miles driven in the United States. When more people use a roadway than the capacity for which it is built, traffic slows. Commercial trucking—the most common method of moving freight across the United States—is increasingly reliant on urban interstate highways, many of which are congested. Between 1982 and 2003 the share of roads in U.S. urban areas that are congested rose from 34 percent to 59 percent. Changes in commuting patterns have also spread congestion to more roads. The traditional suburb-to-city commute has diminished in importance: As of 2000, half of all commuters drove to jobs in the suburbs, while only 20 percent drove to jobs in central cities.

Congestion is defined as the marked slowing of traffic as a roadway reaches capacity. Congestion in the United States manifests itself primarily as a bottleneck on a roadway (see Chart 6-5). A bottleneck is a hindrance to vehicle movement because it involves delays at key intersections, backed-up traffic, or narrow or obstructed sections of a roadway. Unexpected events such as accidents or other traffic incidents also cause congestion on crowded roadways. Together, they are responsible for 65 percent of all congestion.

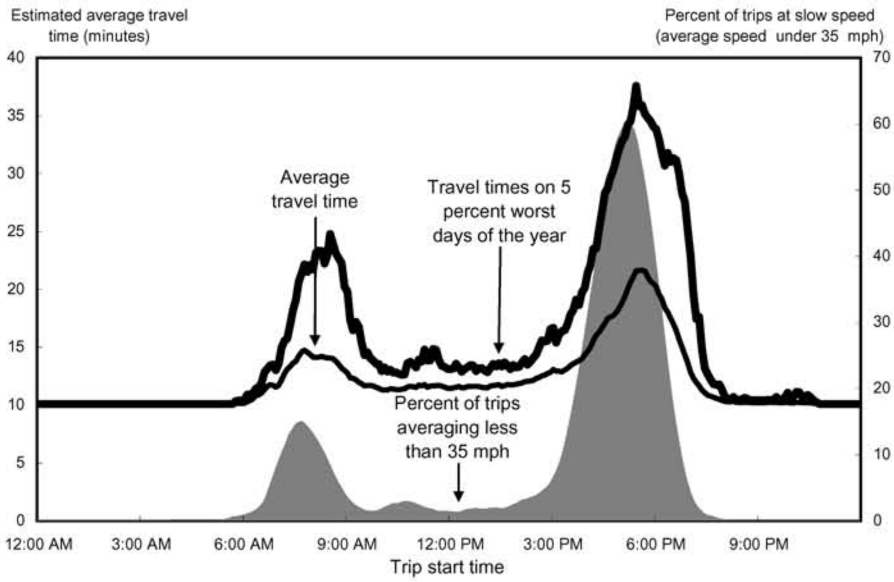
Chart 6-5 **Main Sources of Congestion**
Bottlenecks and traffic incidents are responsible for causing 65 percent of congestion on U.S. roads.



Source: Department of Transportation (Federal Highway Administration).

It is important to note that roadways are not congested at all hours of the day. For instance, on one particular roadway in the Seattle area, a trip that occurs prior to 6 a.m. or after 10 p.m. takes about 10 minutes (see Chart 6-6). That same trip takes about 30 percent longer at 8 a.m. and almost twice as long at 6 p.m. due to slowing traffic. This general trend appears in many U.S. cities and suggests that it is the timing of vehicle miles traveled more than their growth that is at the root of the congestion problem.

Chart 6-6 **Travel Time and Hour of Day on I-90 from Bellevue to Seattle**
Roadways are not congested at all hours of the day.



Note: Travel times are for general purpose (non-HOV) lanes.
Source: Washington State Department of Transportation.

One underlying reason why congestion exists on U.S. roadways is the lack of a private market to price roadway use. Most roads in the United States are provided by the government, are open to all, and are free of charge. Economists generally believe that a good may be better provided by the government when it is difficult for private markets to charge for its use. Because one motorist's use of a congested road reduces the road's value for other drivers and drivers can be selectively prevented from entering the roadway through the use of gates or technologies that monitor use, it is increasingly appropriate to charge drivers for some roadway use in the same way the private market charges for other goods and services.

A driver decides which road to use based on private needs: for instance, the shortest distance or fastest route between destinations, or the closest, most accessible highway. The fact that each driver decides on a route independently of other drivers is not a problem when the number of drivers is well below the roadway's capacity. However, when drivers have free access to roads, crowding occurs at times of high demand, decreasing vehicle speed and flow. Each additional driver slows down other drivers on the roadway, causing them to lose time and to burn extra gasoline. However, drivers typically do not consider the added costs they impose on others. This is a "get in line" or "queuing" approach to allocating road space. When there is a shortage of something—

for instance, space on a ski lift, or attendants at the Department of Motor Vehicles—those willing to get in line and wait eventually receive what they want. This approach to road-use management is inefficient because it allocates road space to those with the time to wait in traffic, not necessarily to those who value its use most highly.

If a roadway is priced—that is, if drivers have to pay a fee to access a particular road—then congestion can be avoided by adjusting the price up or down at different times of day to reflect changes in demand for its use. Road space is allocated to drivers who most highly value a reliable and unimpaired commute. This arrangement encourages drivers to consider the tradeoff between the price of using the road and the additional time and inconvenience of using a nonpriced, alternate route, or driving at a noncongested time. Drivers who place a high value on the predictability and reduced time of commuting, for instance, a doctor who has been called to the hospital for an emergency, have the option to pay for access to noncongested roads. Drivers with more time flexibility, for instance a person doing his or her grocery shopping, can avoid the road and the fee. They can use alternative but more congested roads, shift when they drive to nonpeak hours, or use mass transit when it provides a cheaper alternative to driving. The average cost to each driver falls because drivers have a choice in how they pay for roadway use, in time or in money.

The Cost of Congestion

Over time, slowing traffic exacts heavy costs on drivers. On average, congestion caused 47 hours of delay for U.S. commuters and commercial truck drivers in 85 urban areas during peak hours in 2003. For America's 13 largest cities, this number is much higher: 61 hours. Extra fuel is consumed on congested roads because of the effect that waiting in stop-and-go traffic has on fuel economy. In 2003, sitting in traffic wasted about 2.3 billion gallons of fuel, or almost 1.4 percent of all fuel consumed by light-duty and commercial vehicles that year. Waiting in traffic can also increase the cumulative amount of pollution emitted from a vehicle's tailpipe, which contributes to poor air quality and more greenhouse gas emissions.

Aggregating over the 85 most congested U.S. cities, the cost of time wasted in traffic and extra fuel consumed by commuters and commercial truck drivers due to congestion is estimated to have exceeded $63 billion in 2003 (see Table 6-1). In Los Angeles, the city with the worst congestion, the fuel and time cost of waiting in traffic was calculated to be almost $1,600 per traveler in 2003. In Philadelphia, congestion is noticeably less than in Los Angeles, but the estimated cost to travelers is still high: $641 per traveler per year. In addition, businesses that rely on regular and on-time delivery of supplies have begun to maintain larger inventories to safeguard against

TABLE 6-1.— *Cost of Congestion in Wasted Time and Fuel in the largest Urban Areas*

Metro area	Annual delay per traveler (in hours)	Total cost ($ in millions)	Cost per peak traveler
Los Angeles–Long Beach–Santa Ana CA	93	$10,686	$1,598
San Francisco–Oakland CA	72	$2,605	$1,224
Washington DC–VA–MD	69	$2,465	$1,169
Atlanta GA	67	$1,754	$1,127
Houston TX	63	$2,283	$1,061
Dallas–Fort Worth–Arlington TX	60	$2,545	$1,012
Chicago IL–IN	58	$4,274	$976
Detroit MI	57	$2,019	$955
Miami FL	51	$2,486	$869
Boston MA–NH–RI	51	$1,692	$853
Phoenix AZ	49	$1,294	$831
New York–Newark NY–NJ–CT	49	$6,780	$824
Philadelphia PA–NJ–DE–MD	38	$1,884	$641

Source: Texas Transportation Institute, 2005 Urban Mobility Report.

unanticipated delays caused by congestion. A recent study conducted by the Department of Transportation confirms that congestion has resulted in higher transportation prices and less reliable pickup and delivery times for freight.

Building More Roads

Expanding road capacity may be an important component of any long-term strategy to accommodate traffic growth in urban areas. However, there are a number of reasons why a construction-only strategy to alleviate congestion is likely not the best solution. First, increasing capacity can take years to complete and is expensive—one study found that a lane costs between $1 million and $8.5 million per mile to build. Second, new lanes are often needed in densely populated areas, but these are often also the areas where it is most difficult to find unoccupied space for expansion, making new lanes politically controversial. Third, a body of evidence suggests that the addition of a nonpriced lane to an already congested roadway may do little to alleviate congestion. This happens for two reasons: new roads generate additional traffic as drivers take trips to destinations that previously took too long to reach. And since traffic flow improves initially, drivers who were previously using alternative, often less congested routes now find the highway with the added lane more attractive. Drivers continue to redistribute themselves across the various routes until the costs of using the new route and the costs of using the existing route are about equal. At this point, no driver can be made better off by changing routes. Ultimately, the reason why building more roads is insufficient is because it does not address the underlying problem: roads are not priced and are therefore subject to overuse.

Pricing Road Space

There is reason to believe that reductions in traffic congestion would be relatively easy to attain. Small changes in the number of cars using a particular roadway at a given time can result in large improvements in the flow of traffic. For instance, the addition of just a few school buses makes traffic flow noticeably worse on the first day of school, while traffic flow is noticeably better on some State holidays when only a small number of residents stay home from work.

Congestion pricing dampens demand for roads during peak hours and spreads usage over a longer time period. Differentiating the price of a good by the time of day effectively allocates limited space during periods of higher demand. This approach is used by many providers of goods and services: movie theaters charge more in the evening than they do midday; ski runs charge more during weekends than they do on weekdays; airlines raise prices on tickets during peak seasons; taxi cabs charge more during rush hour; and railroads often charge lower prices for offpeak traveling.

In addition to improved allocation of road space, charging a fee also provides urban planners with useful information about when and where to invest in the expansion of existing road capacity. Expansion should be focused on roads where drivers demonstrate a willingness to pay that is higher than the costs of construction. Revenues from roadway pricing may also prove a viable alternative to taxes as a way to fund the building of new roads in urban areas. As is the case in other markets, those who use the roadway would pay for its maintenance and expansion.

In general, there are two ways to price road space to address congestion: cordon pricing and roadway pricing. *Cordon pricing* charges a toll to vehicles for access to a congested area regardless of which roads in the area are used. It is typically in effect during the work week and varies by time of day. Cordon pricing has been implemented in a number of cities including London, Stockholm, and Singapore. While cordon pricing has been considered for several cities in the United States, it has not yet been implemented here. It is likely to be less effective in cities that are less dense, do not have adequate public transportation systems, and have multiple areas of centralized economic activity (such as Phoenix or Los Angeles).

Evidence suggests that cordon pricing fees have been effective in reducing congestion where they have been tried. After the first year that cordon pricing was imposed in London, for instance, congestion fell by 30 percent, average vehicle speed increased by 20 percent, and bus travel became more reliable (see Box 6-2). One important mechanism for reducing congestion appears to be the ability to substitute some form of public transportation for driving.

Box 6-2: Cordon Pricing Experiences in London and Stockholm

In London, drivers pay an 8-pound fee for daily access to a portion of downtown between the hours of 7:00 a.m. and 6:30 p.m. on weekdays. There are no toll booths around the perimeter of this area. Instead, cameras record the license plates of vehicles and check them against a list of prepaid vehicles. Drivers have a variety of choices in how they pay: they can pay at designated service stations, through the Internet, by text message or phone, or by mail. Weekly and monthly charges also are available for regular commuters. If drivers have not prepaid, they have until midnight of the next day to do so. Anyone who drives within the zone without paying during this time period is fined 100 pounds through an automated system.

Stockholm also recently implemented cordon pricing, but it differs from the London system in two ways. First, it charges vehicles via a card mounted on the windshield that is read electronically by roadside beacons when cars drive past them. Second, Stockholm uses a variable pricing system, which means that the fee is higher during rush hour periods.

A recent report on the London policy indicates that cordon pricing has led to a 30 percent reduction in delay time for city commuters. Initial reports from Stockholm's 6-month test period indicate that there were decreases in traffic of about 22 percent due to cordon pricing. Large reductions in London and Stockholm traffic were due in part to increased use of bus transit. In spite of early criticism from drivers and businesses within the central city, cordon pricing has grown in popularity in London. In Stockholm, this has also been the case: a majority of residents voted to retain cordon pricing after the test period ended.

Roadway pricing aims to limit congestion on certain routes by charging variable fees (tolls) to access a particular lane or road, regardless of the final destination. Ideally, road tolls should be responsive to the actual level of congestion at each moment. By increasing the fee during periods of high demand and reducing it during periods of low demand, the variable tolls reduce congestion by encouraging offpeak driving and the use of alternative routes.

Variable tolls are rare in the United States. Most of the over 5,000 miles of toll roads in the United States have flat tolls designed to generate revenue, rather than variable tolls to relieve congestion. Where they do occur, they are typically limited to a single road or freeway. On the congested bridges and tunnels connecting New York and New Jersey, tolls are discounted by

20 percent ($1.00) during nonpeak hours. Results of a small survey indicate that about 7 percent of drivers changed their behavior as a result of these variable tolls. The most common changes were to switch to mass transit, carpool, or to increase offpeak driving.

Recently, the Department of Transportation helped fund a small pilot project in Seattle to examine how drivers would respond if the entire road system in the city were subject to a variable tolling system. Where and when participants drove was automatically tracked and transmitted by a device installed in their car. Participants received prepaid accounts between $600 and $3,000 to pay the tolls. At the end of the pilot, they were allowed to keep whatever they did not spend. Tolls ranged from 5 to 50 cents per mile and varied by road and time of day. Preliminary results show that nearly 80 percent of participants decreased the amount they drove or changed when they drove. On average, participants took 5 percent fewer trips by automobile and drove 2.5 percent fewer miles each weekday due to tolls. Participants took 10 percent fewer trips and drove 4 percent fewer miles during the morning commute.

Currently, there are about six U.S. highways that use high-occupancy toll (HOT) lanes, many of which incorporate variable pricing and were piloted using Federal funds. HOT lanes are variations of the high-occupancy vehicle (HOV) lanes discussed earlier in the chapter, but they have greater potential to reduce congestion since they are less likely to be underutilized. Similar to HOV lanes, they allow carpoolers to use the road for free or at a discount but charge a toll to single occupancy drivers for access. The toll frequently varies by time of day. Some tolls set variable prices based on historical highway use and adjust rates monthly or quarterly. Other tolls use real-time information on congestion conditions to adjust tolls dynamically over the course of the day. In locations where HOV lanes are underutilized, conversion to HOT lanes is suggested as a way to increase use and to provide more choice to drivers. For instance, in San Diego, conversion of HOV lanes to HOT lanes on a portion of Interstate 15 increased usage by 64 percent over a 3-year period. Several studies confirm that there are substantial gains in societal welfare from allowing solo drivers to pay for access to existing HOV lanes. Others caution, however, that when only one HOV lane is converted to a variable toll and other lanes are free of charge, any temporary decrease in congestion on the remaining free lanes may be offset by the redistribution of traffic.

The use of real-time or historically based variable tolling on HOT lanes may have a significant effect on traffic flow. For instance, San Diego's variable toll uses real-time pricing, which changes every 6 minutes to reflect the amount of traffic on the road. Computerized electronic signs make information on the toll amount and the speed and flow of traffic available to drivers before they have to decide between the free and priced lanes. Results show that travel times vary little on San Diego's variable toll lanes because free-flow conditions are almost always maintained. In Orange County, the tolls vary by hour and day of the week, but are based on historical information. While they are adjusted several times each year, the toll does not convey actual conditions to drivers, only average conditions. Thus, unexpected events such as accidents can cause major delays on the variable toll lanes and because drivers do not have up-to-date information on road conditions, travel time is less predictable.

Despite their potential benefits, toll lanes are sometimes portrayed as "Lexus Lanes." The contention is that tolled roadways supply faster routes only to high-income drivers who can afford to pay the tolls, while lower income drivers continue to be stuck in traffic. One study finds that drivers with higher incomes tend to use HOT lanes more often than lower income drivers, but that lower income drivers rely on toll lanes when on-time arrival at their destination is important. For instance, you can imagine a case where a parent is running late, but needs to be at the daycare to pick up his or her child by a certain time. If the parent is late, and the daycare fines him or her $10, then paying a $4 toll to arrive on time saves $6. A recent survey also finds that support for or opposition to HOT lanes is unrelated to income. Another study finds that lower income, bus commuters were some of the largest beneficiaries of cordon pricing in London. Bus riders are exempt from paying the cordon fee, but their commute times greatly improved. Not surprisingly, the number of bus passengers during morning hours increased.

Experts note that implementation of congestion pricing faces less resistance where motorists are unaccustomed to free and unrestricted roadway access. For instance, it may be more feasible to implement congestion pricing on a new road than on an existing road. Likewise, it may be easier to convert HOV lanes to HOT lanes. The advent of new technologies that electronically charge the toll by sensing a microchip placed on the windshield of the vehicle eliminates the need for a driver to stop and physically pay the toll. These are increasingly used to charge drivers tolls on existing roadways, making congestion pricing systems easier and less costly to implement.

Historically, one of the largest hurdles to variable price tolling on roadways in the United States has been the Federal-aid highway program, which has prohibited states from collecting tolls on interstates or other roads that receive Federal funding. Federally funded pilot projects that explored variable price tolling brought the advantages of congestion pricing to the attention of policymakers. Policymakers also began to explore the use of pricing mechanisms to reduce congestion in other contexts, such as for allocation of runway access at airports (see Box 6-3). A transportation bill signed into law in 2005 (The Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users) provides states with increased flexibility to use tolling to manage congestion and finance infrastructure improvements, and provides ways to participate in pilot demonstrations of variable tolling. States such as Texas and Colorado have passed laws allowing the formation of toll authorities at local levels that can then construct and operate toll roads. States such as Washington, California, Florida, and Minnesota have identified candidate freeways for variable tolling.

Box 6-3: Airport Pricing to Decrease Congestion

Though traffic jams are easily observable manifestations of congestion, flight delays and runway bottlenecks also waste time and fuel. Landing fees at most U.S. airports are directly related to the weight of the plane, even though lighter and heavier planes tend to consume approximately the same runway time. This contributes to airport congestion because it encourages smaller, lighter planes (which can use smaller satellite airports) to overuse the airport, displacing larger, heavier passenger planes and reducing the number of passengers that an airport can serve at a time.

A short-lived experiment at Boston's Logan airport in 1988 demonstrates how a change in the landing fee structure can effectively reduce airport congestion. Boston changed its runway use fee from one based only on aircraft weight to one that combined a non-weight-based fee and a smaller weight-based component. The fee for a small single-engine plane increased from $25 to about $100, while the fee for a large jumbo 747 jet decreased from $800 to less than $500. By flattening the landing fee, Logan made it relatively more costly to land small planes, decreasing their volume. This allowed it to more easily accommodate the larger planes that carry more passengers. The result was that Logan airport reduced delayed landings from 30 percent to 14 percent in less than 4 months. Despite a reduction in congestion, the new landing fee structure abruptly ended when the program was deemed to be in violation of the Federal Aviation Act.

The auctioning of runway access for planes may prove to be an even more effective way to reduce congestion at airports. An auction would award landing rights to the carrier that values the slot the most. Such auctions have been successful in other contexts such as to allocate radio waves while still accommodating smaller local and public radio stations.

Conclusion

The transportation industry relies overwhelmingly on petroleum for fuel. In spite of its reliance, the market largely functions as it should; while transportation is particularly unresponsive to changes in oil prices in the short run due to the lack of readily available substitutes, it does eventually respond. Also, the price reflects the costs to the firm of producing the oil and the benefits to drivers from consuming the oil. That said, the use of oil by the transportation and other sectors generates costs to national security and the environment that users typically do not take into account. Likewise, the full costs of congestion are not taken into account by individual users when they drive, since roadway use is not priced by the market. Carefully crafted policies could help address these costs but care should be taken as government action itself imposes inefficiencies.