CHAPTER 8

IMPROVING THE QUALITY OF LIFE THROUGH SMART REGULATION, INNOVATION, CLEAN ENERGY, AND PUBLIC INVESTMENT

Recent years have seen an unprecedented number of official efforts to improve, develop, and implement new measures of the quality of life and economic performance. Much of the groundwork for these efforts was laid in two important National Research Council reports. *Nature's Numbers*, published in 1999, considered how to expand the national income accounts that track the country's economic activity to properly take into account the environment and natural resources. *Beyond the Market*, published in 2005, proposed ways to integrate nonmarket activity into the accounts.

This work has implications for economic policy. Carefully designed regulations can promote economic growth and improve the Nation's quality of life. Water pollution, for example, can cause illness and destroy the livelihood of fishermen and others who rely on a healthy ecosystem to earn a living. Pollution, as Robert Kennedy noted, does not subtract from the gross domestic product. Appropriately balanced efforts to restrict harmful pollution can improve economic performance along with the health and safety of Americans.

The theme of this chapter is that, properly measured, both economic growth and the Nation's well-being can be increased by smart regulation, innovation and public investment in such fields as medical research, clean domestic energy and transportation infrastructure.

A Smart Approach to Regulations

For more than a century, the United States has been a world leader in protecting the health and safety of its citizens through well-chosen regulations. Fuchs (1998 and 2010) attributes gains in life expectancy prior to World War II to improvements in "nonmedical factors: nutrition, sanitation, housing, and public health measures." For example, in response to yellow fever and cholera outbreaks caused by water pollution, the Rivers and Harbors Act of 1899 gave the Army Corps of Engineers the authority to regulate the discharge into waterways of "refuse matter of any kind or description." Similarly, public health concerns about unsanitary meat packing conditions and patent medicines containing narcotics gave rise to the Pure Food and Drug Act of 1906, which authorized the Food and Drug Administration (FDA) to inspect food and drug products and regulate their sale. In 1900, roughly one in every 200 Americans was addicted to narcotics found in patent medicines (DOJ n.d.). Following the disclosure requirements in the Pure Food and Drug Act, sales of patent medicines containing those substances fell by nearly a third (Musto 1999).

As society evolves and technology changes, such basic protections afforded to citizens through regulation are updated and improved. Today, the water pollution controls provided for in the Rivers and Harbors Act have been incorporated into more expansive provisions in the Clean Water Act of 1972 and the Safe Drinking Water Act of 1974, which enable the Environmental Protection Agency (EPA) to promulgate regulations with the goal of making U.S. waters safe for drinking, swimming, and fishing. Similarly, the Pure Food and Drug Act of 1906 was amended by the Food, Drug, and Cosmetic Act of 1938 to give the FDA the authority to require evidence of safety for new drugs and to tighten food quality standards. It was amended again in 1962 to require manufacturers to prove drug effectiveness (Randall 2001). Most recently, the Food Safety Modernization Act of 2010 further improved the safety of food sold in the United States by, among other provisions, giving the FDA the authority to directly issue mandatory food recalls, requiring food processors to have plans in place for addressing safety risks, and requiring importers to verify food safety.

Measuring the benefits of regulations for the quality of life is a formidable task. Some forms of regulation have a positive effect on economic growth, for example, by improving the health and vitality of the workforce, by promoting stable and efficient operation of financial markets, by speeding the adoption of energy-saving technologies, by improving educational outcomes, or by upgrading the operation of the transportation system. Much of the benefit from those types of regulations eventually translates

into increases in GDP. In other cases, such as the protection of the National Park System, safeguards against invasive species, or cleaner lakes for swimming and fishing, the benefits of regulation help the economy, but are less easily charted in the national accounts. For example, increased tourism or higher returns to commercial fishing resulting from cleaner water would be reflected in GDP, whereas the public's increased appreciation of that cleaner water would not be.

Designing Smart Regulations

On January 18, 2011, President Obama issued Executive Order 13563, "Improving Regulation and Regulatory Review," which lays out a balanced approach to regulation—to protect the health and safety of the American people in a way that maximizes net benefits to society, that uses the best information available, and that avoids unnecessary or overly burdensome requirements. The President called for an agency-wide review to reduce burdensome regulations. Underlying that approach is a belief that a smart, effective regulatory system depends on careful analysis of costs and benefits, both before and after regulatory action, including an informed public discussion. The Executive order directs the Office of Information and Regulatory Affairs (OIRA) of the Office of Management and Budget (OMB) to provide oversight, transparency, and discipline for executive agencies in the regulatory process, and coordinates that interagency review of rulemakings to ensure that regulations are consistent with applicable law. The net benefits of regulations finalized in 2011 are expected to be at their highest level in the last 10 years. And monetized savings from the retrospective review of regulations called for in the new Executive order are likely to exceed $10 billion over the next five years.

Many of those regulations are intended to improve the quality of life by correcting market failures that lead to unsafe living or working environments. Effective regulations put into place rules that correct for significant market failures and thus achieve greater social benefits. "Smart regulations" are those that maximize the net benefits of a regulatory action to society. Benefit-cost analysis attempts to quantify and assign dollar values to the various effects of a regulation, which can be used to determine how it can reach its goal in the most efficient manner—that is, how it can generate the largest net benefits (the difference between total benefits and total costs) to society. Such information is useful for both policymakers and the public, even when economic efficiency is neither the only nor the overriding public policy objective, as in the case of protecting privacy.

Benefit-cost analysis is used to estimate likely future benefits and costs of a proposed regulation, but it can also be used to "look back" at existing

regulations, based on evidence about the actual, realized benefits and costs of those regulations. Such retrospective analyses can be used both to improve existing regulations and to better evaluate new ones.

Smart regulations thus seek to use the best information available in order to maximize net benefits by setting regulatory stringency at the most efficient level—the point at which the incremental benefits are equal to the incremental costs. For example, even though the marginal costs of seat belt standards increased over time (front-seat shoulder and rear-seat lap belts were mandated for cars in 1968 and for light trucks and vans in 1971, and three-point belts were required in the mid-1970s), those costs were far outweighed by the corresponding number of lives saved per year by seat belts (DOT 2004; Kahane 2004). The buckle-up laws of the mid-1980s raised the number of lives saved by wearing seat belts to 6,000 a year by 1988–90, and subsequent increases in belt use raised the annual number of lives saved to more than 15,000 in each year from 2003 to 2007. All together, between 1975 and 2009, seat belt regulations saved an estimated 268,000 lives (Kahane 2004; DOT 2009). (For another example of how benefit-cost analysis works, see Economics Application Box 8-1.)

Smart Regulations in Practice

Benefit-cost analysis has long been used to evaluate regulations within the Federal Government. For example, the Flood Control Act of 1936 declared that "the Federal Government should improve or participate in the improvement of navigable waters or their tributaries including watersheds thereof, for flood-control purposes if the benefits to whomsoever they may accrue are in excess of the estimated costs, and if the lives and social security of people are otherwise adversely affected."

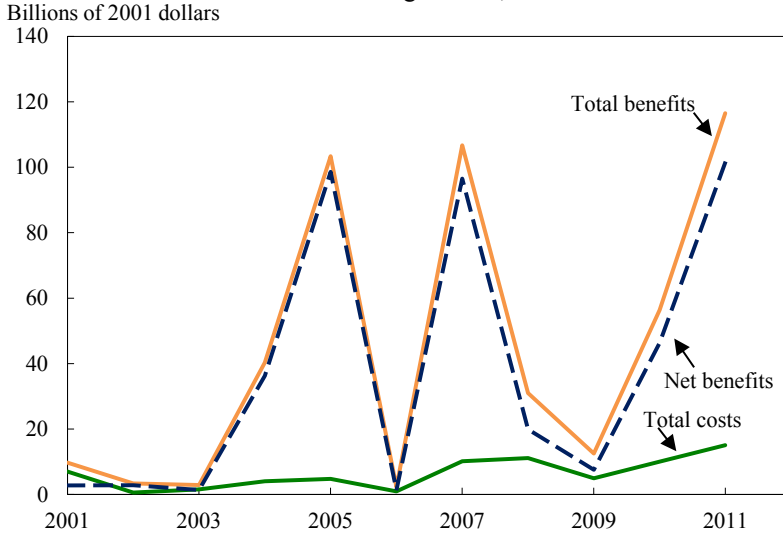
The use of benefit-cost analysis in evaluating Federal regulations has become widespread since 1981, when President Reagan issued Executive Order 12291, formally requiring that "regulatory action shall not be undertaken unless the potential benefits to society for the regulation outweigh the potential costs to society and that regulatory objectives shall be chosen to maximize the net benefits to society." President Clinton issued Executive Order 12866, which focused OIRA oversight on "significant" rules and increased transparency. As noted earlier, President Obama issued Executive Order 13563, which reaffirms the principles in Executive Order 12866 and outlines a regulatory strategy to support continued economic growth and job creation. In particular, Executive Order 13563 offers new directions for regulatory review, including a requirement that agencies "use the best available techniques to quantify anticipated present and future benefits and costs as accurately as possible" while authorizing consideration of "values that are

difficult or impossible to quantify, including equity, human dignity, fairness, and distributive impacts."

Based on the quantified benefits and costs in current regulations, smart regulations are generating the highest level of net benefits for U.S. citizens in the last decade. In calendar year 2011, the Administration completed 740 regulatory reviews, 336 of which were interim final or final rules from executive agencies. Of the interim final and final rules reviewed, 18 percent were "economically significant," meaning that they are anticipated to have an effect on the economy of more than $100 million in any given year. Those economically significant rules are expected to result in $15 billion in costs and $116 billion in benefits annually (in 2001 dollars). Over the past three calendar years, the annualized net benefits of completed rules have totaled about $155 billion. In 2011 alone, annualized net benefits totaled more than $101 billion. Those figures reflect an estimate of not only purely monetary savings, but also an estimate of the monetary value of prevented deaths, illnesses, and injuries. Figure 8-1 shows the benefits and costs of regulations, which are detailed in the agencies' Regulatory Impact Assessments for each economically significant rule and summarized annually in OMB's annual Regulatory-Right-to-Know report to Congress.

Data and estimation methods have improved substantially over time, as have modeling tools for projecting a regulation's effect into the future. For

Figure 8-1
Benefits and Costs of Regulations, 2001–2011



Note: Total benefits, total costs, and net benefits are based on the midpoints of agency estimates for regulations completed during the calendar year.
Source: Office of Information and Regulatory Affairs.

Economics Application Box 8-1: Comparing Benefits and Costs

How do policymakers determine whether a regulation is a smart regulation? For example, in 2007, the Department of Transportation (DOT) decided to require that all new passenger vehicles weighing less than 10,000 pounds be equipped with electronic stability control (ESC) systems, which reduce crashes by improving braking in critical situations when the driver is beginning to lose control. This rule will increase the fraction of new vehicles with ESC from 29 percent in 2006 to 100 percent in 2012. How did the DOT decide this was a smart regulation?

First, the DOT identified what is arguably a market failure: a relatively affordable technology existed that lowered the risk of a crash, but it was not being offered by some manufacturers and, when offered the choice, many consumers declined. This market failure was caused by asymmetric information (drivers purchasing a vehicle could not fully assess the protection afforded by ESC systems) and by a negative externality (consumers purchasing a car without an ESC system did not fully account for the risks of a crash to others).[a]

Second, the DOT then examined the likely costs and benefits of equipping all passenger cars and light trucks/vans with ESC by model year 2012. Approximately 17 million vehicles will be subject to this regulation; however, DOT estimates that as of 2011, manufacturers would have installed ESC in 71 percent of their fleet absent the rulemaking. Therefore, both the benefits and costs were calculated by raising ESC installation from that baseline of 71 percent to 100 percent. The benefits of the rule include reductions in fatalities, injuries, property damage, and travel delays, all resulting from fewer accidents. To monetize those benefits, the DOT multiplied the total number of loss-of-control crashes by the average effectiveness of ESC systems and found that 67,000–91,000 crashes would be avoided each year. Using historical accident data, DOT estimated that a decline of 67,000 crashes would reduce total annual fatalities by 1,547 and decrease total annual injuries by 46,896.[b]

The monetary value of those benefits depends on the discount rate, that is, on how much benefits in the future are worth today (a high discount rate implies that people discount the future more and thus any benefits that accrue in the future would be valued less today). At a 7 percent discount rate, the reduction in injuries and fatalities translates into $6.4 billion in benefits; at a 3 percent discount rate, those benefits are $8.0 billion, as the Box Table shows. To determine the noninjury component of benefits, the DOT multiplied the individual unit costs for travel delays and property damage by the 67,000 crashes that would be prevented by the rule, yielding $247 million in benefits at the discount rate of 7 percent.

Annual Costs and Benefits by Discount Rate
Millions of 2005 dollars

	3% discount	7% discount
Injury and fatality benefits	$7,965	$6,360
Savings from reduced property damage and travel delays	309	247
Total benefits	8,274	6,607
Vehicle costs	985	985
Fuel costs	27	22
Total costs	1,012	1,007
Net benefits	7,262	5,600

Note: Vehicle costs are not discounted, because they occur when the vehicle is purchased, whereas benefits occur over the vehicle's lifetime and are discounted back to the time of purchase.
Source: Department of Transportation, National Highway Traffic Safety Administration (2007).

The DOT determined that production costs would rise by between $111 and $479 for each affected vehicle, depending on whether the vehicle was already equipped with anti-lock braking systems, a necessary component of ESC. The expected costs of the standard above the baseline total $985 million. Because the average weight of passenger cars is expected to increase by 2.1 pounds as a result of the new equipment, the lifetime fuel use of those vehicles is expected to go up by 2.6 gallons. At discount rates of 7 percent and 3 percent, the total additional fuel costs are $21.8 million and $26.8 million, respectively. Summing vehicle and fuel costs gave the total costs of the regulation: about $1.0 billion. Net benefits, then, are the difference between total costs and total benefits, or between $5.6 billion and $7.3 billion each year for the lower range of accident prevention.

[a] For further discussion of market failures and automobile safety standards, see Mannering and Winston (1995), Arnould and Grabowski (1981) and Viscusi and Gayer (2002).

[b] The appropriateness of including private benefits net of private costs in a benefit-cost analysis varies from rule to rule. By including private net benefits—the value of reducing injuries and fatalities of the consumers minus the purchase cost of the technology—the DOT is making the implicit assumption that consumers have made a suboptimal purchasing decision (one of the market failures being addressed by the regulation). However, if consumers do not face an information problem, a traditional approach would assume that consumers have made the purchasing decision that maximizes their welfare. If this were the case, it would be inappropriate to include those private net benefits in the analysis. For further discussion, see Gayer (2011).

example, the health benefits from reducing different air pollutants over different time periods and populations have been estimated by epidemiologists using air quality monitoring data and various health endpoints (EPA 2011a). Improvements in computing power and data records now allow air quality modelers to forecast the effects of regulatory actions on future air quality under different scenarios. Combining those estimates allows policymakers to weigh the expected health results of a given air quality regulation with the expected costs associated with the controls required by the rule.

A peer-reviewed study by the EPA using the Criteria Air Pollutant Modeling System estimated that the Clean Air Act prevented more than 160,000 premature deaths, 54,000 cases of chronic bronchitis, 130,000 nonfatal heart attacks, and 1.7 million cases of asthma exacerbation between 1990 and 2010. Those adverse health outcomes could have led to 86,000 emergency room visits for respiratory problems, 3.2 million lost school days, and 13 million lost work days (EPA 2011b).

Some health benefits from Clean Air Act regulations will likely raise economic growth indirectly and over time through intermediate factors. For example, a healthier population will arguably be a more productive one, a change that can be measured in improved labor productivity. A growing consensus has identified certain of those intermediate drivers of growth, including increased human capital, capital investment, research and development, economic competition, physical infrastructure, and good governance. Some evidence strongly suggests that regulations promoting educational attainment may improve human capital accumulation, thereby increasing economic growth over time (for example, see Cohen and Soto 2007). Other studies show a positive link between increased life expectancy and economic growth. A survey of the existing literature on health and economic outcomes (Bloom et al. 2004) finds in cross-country analysis that a one-year increase in life expectancy generates a 4 percent increase in economic output, controlling for other variables. Similarly, Murphy and Topel (2006) find that progress made battling various diseases after 1970 added about $3.2 trillion a year to national wealth.

Retrospective Analysis

The prospective benefit-cost analysis that goes into crafting smart, efficient regulations is necessarily fraught with uncertainty. Prospective analysis requires that the costs and benefits of a regulation be identified and quantified before (*ex-ante*) the regulation is implemented. Only after a

regulation has gone into effect can its actual (*ex-post*) effects become known (see Data Watch 8-1).[1]

Changes in technology often make pollution abatement cheaper. For example, the actual costs to utilities of the cap-and-trade system for sulfur dioxide allowances set up by the Clean Air Act Amendments of 1990 were much lower than had been predicted. Scrubbing technologies turned out to be more efficient at removing sulfur dioxide from emissions, and power plants were able to blend a higher percentage of cheaper, low-sulfur coal than had initially been assumed. Moreover, the benefits of reducing sulfur dioxide emissions have since been found to be much larger than originally thought. As a result, subsequent regulations for utilities have tightened controls on those emissions.

Similarly, during the 1970s, automobile technologies were improved by new pollution standards. Regulators were phasing lead out of gasoline, and again the costs of the regulation were overestimated and the benefits underestimated. Lead impairs brain development in children and has been linked to serious health problems in adults such as hypertension, heart attacks, and premature death (Lovei 1998). Concern about high blood lead concentrations in the U.S. population led the EPA to begin in 1974 to phase in a stringent standard reducing the amount of lead allowed in the gasoline supply. Subsequent studies found that the annual benefits of banning lead in gasoline would be more than $6 billion (in 1983 dollars), but would cost around $500 million a year (Schwartz 1985). Harrington, Morgenstern, and Nelson (1999) note that those costs may have been overstated, but that it was difficult to disentangle the effects of a phase-out of leaded gasoline from the much larger effect of changes in oil markets around that time. Research also found that the benefits of lowering lead exposure were greater than initially thought. The EPA's 1985 benefit estimate implied that reducing mean blood lead concentrations in the population by 1 microgram per deciliter (or 1 μg/dl) was worth at least $3.5 billion a year (Schwartz 1994). By 1994, however, researchers were finding that a reduction of 1 μg/dl in mean blood lead concentrations resulted in much greater benefits than earlier estimates—as high as $17.2 billion a year (1989 dollars) (Schwartz 1994). The phase-out of leaded gasoline was completed in 1995; by then the average blood lead concentration was approximately 2.3 μg/dl, down from more than 15 μg/dl in the early 1970s (Weaver 1999).

[1] Retrospective analyses of benefits and costs are also subject to uncertainty, because they require evaluation of a counterfactual scenario in which the rule was not adopted. Identifying that counterfactual is often difficult, in part because changes that occurred due to the rule are difficult to distinguish from changes that the industry would have adopted voluntarily.

Data Watch 8-1: The Value of Information—the PACE Survey

One of the few data sources for benchmarking costs of air and water pollution controls is the Pollution Abatement Costs and Expenditures (PACE) survey, which recently has been funded by the Environmental Protection Agency (EPA) and administered by the Census Bureau. From 1973 to 1994, the PACE survey was administered annually to nearly 20,000 manufacturing and mining facilities and electric utilities. Since 1994, because of resource constraints, the Census Bureau has conducted this survey only twice (for 1999 and 2005). To estimate the overall regulatory burden facing American manufacturers, the PACE survey collects data on overall pollution abatement expenditures by manufacturers for treatment, prevention, recycling, and disposal, rather than trying to allocate costs to specific regulations. It is the only survey that measures environmental compliance costs at both the individual and aggregate levels (Ross et al. 2004).

Pollution equipment expenditures have fallen over time, on average accounting for 7 percent of all investments made by manufacturing industries in the early 1990s and 4 percent in 2005. There is considerable variation in spending across industries, but given that pollution levels (and the negative externalities associated with pollution) also vary by industry, that is neither surprising nor necessarily suboptimal.

The EPA has used PACE data to estimate the cost of both past and proposed regulations (see for example, Gallaher, Morgan and Shadbegian 2008). Academics have used the data set to investigate the relationship between EPA regulations and economic outcomes. For example, Levinson (1999) used the PACE data to develop a new index of state environmental compliance costs. Similarly, Shadbegian and Gray (2005) examined the relationship between of pollution abatement and productivity. And Becker (2005) found expenditures on environmental compliance for small facilities differ from larger facilities.

"Look-Back" Initiative

President Obama's Executive Order 13563, issued in 2011, directed executive agencies to conduct retrospective reviews of their regulations to determine whether any of the agencies' regulations should be modified, streamlined, expanded, or repealed. This Executive order was followed by Executive Order 13579, which called on independent agencies to conduct such retrospective reviews to the extent possible. Look-back exercises enable regulatory agencies to learn whether they can increase net benefits by modifying existing regulations, expanding regulations, or even eliminating existing regulations that may turn out to be ineffective or duplicative.

Incorporating *ex-post* benefits and costs of regulations is the key goal of the new Executive order requiring agencies to conduct retrospective reviews of their regulations. In the past, agencies have undertaken such reviews in certain situations but only on an *ad hoc* basis. The new Executive order aims to improve regulatory analyses by providing a formalized process for incorporating new information into regulations and for gaining insight into the costs and benefits borne by the private sector in practice.

The President's regulatory look-back initiative has produced more than 500 reform proposals, detailed in 26 agency plans, and monetized savings from this review are likely to exceed $10 billion over the next five years. A number of recent actions eliminate or streamline unjustified or excessive regulations, and the Administration has put in place an improved regulatory system that will generate more current and accurate information on regulatory costs and benefits. Moreover, pursuant to Executive Order 13579, issued in July 2011, some of the major independent regulatory agencies have also issued preliminary retrospective review plans for public comment.[2] Five examples illustrate the effectiveness of the look-back initiatives.

First, the Occupational Safety and Health Administration (OSHA), has announced a final rule that will eliminate redundant reporting burdens; the regulation is expected to save employers 1.9 million hours and $40 million annually. OSHA also plans to finalize a rule projected to result in more than $585 million in savings each year by making U.S. hazard classifications and labels consistent with other nations.

Second, since the 1970s, the EPA has treated milk as "oil" subject to regulations designed to prevent oil spills. In response to feedback from the agriculture community and the President's Executive order, the EPA recently concluded that the rules placed unjustifiable burdens on dairy farmers and decided to exempt milk from those regulations. That exemption will save the dairy industry, including many small businesses, as much as $148 million per year.

Third, to reduce burdens on railroads, the Department of Transportation has proposed to refine its requirements for tracks that are to be equipped with positive train controls. This equipment can automatically control a train in emergency circumstances, reducing the risk of an accident. The potential refinements would eliminate the need for costly wayside components and mitigation measures along as much as 10,000 miles of track where they are not needed for safety. The initial 5-year savings are expected to be as high as $335 million, with total 20-year savings of up to $778 million.

[2] Specific retrospective analyses by executive and independent agencies can generally be found on the relevant websites; for example, the Federal Trade Commission provides information on its retrospective review process at http://www.ftc.gov/ftc/regreview/index.shtml.

Fourth, the EPA has proposed to eliminate a requirement for air pollution vapor recovery systems at local gas stations in many states, on the ground that modern vehicles already have effective air pollution control technologies. The anticipated annual savings from eliminating the requirement are estimated to be as high as $87 million.

Fifth, the Health and Human Services Department has proposed or finalized several rules that reduce regulatory burdens and restrictions on doctors and hospitals and that are expected to save more than $5 billion over the next five years.

There are many other look-back efforts—in all, the initial round of retrospective proposals is expected to eliminate millions of hours of required paperwork for individuals, businesses, and State and local governments and to save billions of dollars.

Improvements in Everyday Life

Every time Americans drive a car, take a breath, swim in a lake, or take a medication they are benefiting from regulations. As noted, such improvements in quality of life often show up in national accounts only as a fraction of their total benefit to society. For example, although the growth and size of the pharmaceutical industry are reflected in GDP, the value of assurances given to the U.S. public that the medicines they are taking have been tested and verified to be effective and safe goes far beyond the measured value of that sector to the national economy.

Similarly, the Clean Water Act and its associated permitting requirements have reduced effluent discharge into U.S. streams, lakes, and estuaries. Putting a price tag on the benefits of being able to swim, fish, and boat in those bodies of water is difficult. Regardless of the value, some of those benefits (for example, increasing expenditures on fishing equipment and recreation) will show up in a calculation of GDP, while many others (such as reducing the level of fecal coliform in the water) will not. The EPA estimates the benefits of reducing discharge of conventional pollutants to U.S. rivers and streams to be approximately $11 billion annually (Bingham et al. 2000).

The EPA's Superfund program, which identifies, investigates, and cleans the Nation's most contaminated hazardous waste sites, has also improved public health. Since 1980 the Superfund program has prevented millions of people from being exposed to hazardous substances by requiring protective and containment measures and the removal from industrial sites of many millions of tons of material contaminated with toxic chemicals such as lead, arsenic, mercury, and benzene (EPA 2011c). Studies have shown that Superfund cleanups have lowered the risk of acute poisoning, improved infant health, and decreased the risk of cancer (Currie, Greenstone, and

Moretti 2011; and EPA 2011c). Those improvements are generally not captured well in GDP for any given year.

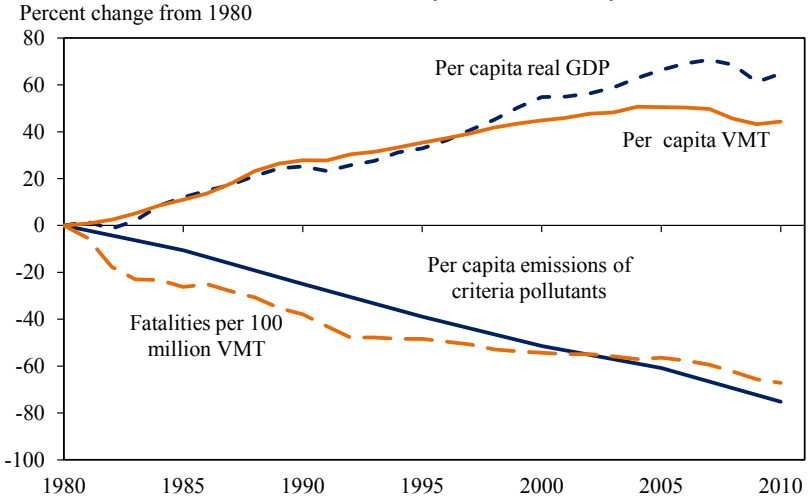
Even though smart regulations can impose restrictions on the private sector, as Figure 8-2 illustrates, the resulting benefits do not come at the cost of prosperity or sacrifices in U.S. standards of living. Over a period of decades, air quality has improved while the economy has grown; indeed, the demand for clean air and water has risen along with income across countries (see for example, Grossman and Krueger 1995; and World Bank 1992). Even though those benefits do not show up directly in GDP measures, they are consistent with increases in conventional (albeit incomplete) measures of growth. Per capita GDP has shown substantial growth between 1980 and 2010, rising by 65 percent, while at the same time per capita emissions of criteria pollutants (lead, carbon monoxide, sulfur dioxide, nitrogen oxides, particulate matter, and ozone) have declined by nearly 75 percent. Similar achievements have been made in other areas as well. The number of fatalities on U.S. roads per million vehicle miles traveled (VMT) has declined by 67 percent between 1980 and 2010, while VMT per capita increased by 44 percent, reflecting the effectiveness of road and vehicle safety regulations.

Innovation

Innovation, loosely defined as the introduction of a new or improved product, service, or process, is the primary source of long-run increases in productivity and human welfare (Grossman and Helpman 1991). When new ideas are integrated into the economy, they offer new possibilities for both production and consumption. Innovation comes in two general forms: process and product innovation. Process innovations involve new or improved methods of production or distribution, often as firms seek to reduce costs. The cost savings are reflected in conventional accounting statistics as greater productivity. Over time, rising productivity drives the growth in the amount of output that the economy can produce. By contrast, product innovations introduce new or improved products or services into the marketplace. As noted, consumers benefit from product innovations in ways that conventional accounting statistics do not adequately measure.

Although there is no perfect measure of the importance of innovation to an economy, by many measures innovation has played an increasingly important role in the U.S. economy in recent decades. For example, the industries classified by the OECD as "knowledge- and technology-intensive" have steadily increased as a share of the U.S. economy, from 34 percent of GDP in 1992 to 40 percent in 2010, according to the National Science Foundation (2010; 2012).

Figure 8-2
Economic Growth, Vehicle Safety, and Air Quality, 1980–2010



Note: VMT is vehicle miles traveled. Criteria emissions are linearly interpolated from 5-year interval data between 1980 and 2010.
Source: National Highway Traffic Safety Administration; Federal Highway Administration; Environmental Protection Agency; Bureau of Economic Analysis.

Private-sector competition is the primary driver of innovation. Firms in innovative industries must continually work to improve their products or increase their efficiency to avoid losing market share to competitors. Businesses that successfully invest in innovations are rewarded in the marketplace. Incentives for businesses to invest in innovation are often less than optimal from the perspective of society as a whole, however, primarily because the innovator may not be able to capture all of the benefits generated by the innovation. The positive spillovers from innovation mean that the private returns from innovation will often be less than the social returns, particularly when it comes to basic research. Private firms have limited incentive to conduct basic scientific research from which they generally can capture only a small fraction of the value that emerges from that research. As a result, private markets may lead to underinvestment in basic science and limited diffusion of scientific advances.

Because private incentives to invest in innovation are often inadequate, public-sector support for innovation has important benefits. Government can promote innovation in many ways. By operating a well-functioning system of intellectual property rights, the government can help innovators earn returns commensurate with the social value of their innovations. Government can increase investment in innovation through research and development (R&D) expenditures, both by direct funding and by tax

incentives. It can facilitate the commercialization of innovations by removing barriers that prevent the private sector from transforming inventions into marketable products. It can provide infrastructure necessary for innovation, for example by allocating spectrum to support the growth of wireless broadband, itself an important platform for innovation in mobile devices, applications, and services. The government can also target innovation initiatives to areas of key public importance, including education, health care, and energy. This section of the chapter discusses these issues and describes some of the Federal Government's current efforts to promote innovation in the U.S. economy.

Measuring Innovation

Innovation's crucial role in economic growth and welfare has prompted efforts to improve the tools to measure it. One longstanding approach to measuring innovation is to infer that any economic growth *not* attributable to additional capital and labor must be due to some sort of "technical change." This so-called "Solow residual" approach (Solow 1957), however, leaves unanswered many questions about the nature of the technical change.

Data on patenting activity can provide a useful, if imperfect, measure of innovation. Although many innovations are kept secret to preserve competitive advantage, many others are made public through patent filings. The innovations for which patents are granted vary greatly in their significance, however, and a raw count of patents cannot account for these differences. Moreover, increases in patent activity over time may be attributable, at least in part, to more aggressive patenting of marginal innovations rather than increases in innovation itself (Hall and Ziedonis 2001). To address these limitations, studies of innovation have often relied on measures of patent citations. For example, the number of times a firm's patents are cited by other patent applications is more closely correlated with the firm's market value than is the raw number of patents it holds (Hall et al. 2001).

New measurement efforts have focused on the funds allocated to R&D within the economy. Historically, R&D has been treated as an intermediate input to the production process and is therefore excluded from GDP estimates. Beginning in 2013, the GDP estimates produced by the Bureau of Economic Analysis (BEA) will include R&D under the category of investment, increasing measured GDP. Spending on R&D is large and growing; if the new definition had been in effect earlier, current-dollar GDP in 2007 would have been, on average 2.7, percent higher, and R&D would have accounted for 6.3 percent of real GDP growth between 1998 and 2007.

In addition, to help improve understanding of the role of R&D in fostering innovation, the Census Bureau and the National Science Foundation (NSF) have introduced the Business R&D and Innovation Survey. This new survey combines firm-level data on R&D expenditures with measures of new or improved products or processes and patenting and licensing activity. The first group of 40,000 for-profit firms was surveyed in 2009, and some preliminary findings have been reported. For example, the NSF reports that companies that invest in R&D exhibit far higher rates of innovation than other firms (Boroush 2010).

Measuring innovation is particularly challenging in the growing medical care sector. For example, medical science has established that aspirin—an old and inexpensive product—can substantially reduce heart attack risk. Patients have seen enormous benefits from that scientific advancement, but those benefits are not captured by estimates of GDP. The National Institute on Aging has sponsored research on the development of national health accounts that would gauge the population's health status and measure how medical care and other factors affect health.

Intellectual Property Rights and Patent Reform

Innovation is spurred in part by the desire to reap rewards for developing new products and services that people will value. The central purpose of intellectual property (IP) rights, which include patents, trademarks, and copyrights, is to promote innovation by giving IP owners the right to exclude others from making use of their novel product or service. Well-designed IP rights enhance the private returns to innovation and bring them closer to the social returns, thereby increasing the incentives to invest in socially valuable innovation. As President Lincoln famously said, the patent system "added the fuel of interest to the fire of genius" (Edwards 2006).[3]

The United States has long had a robust system of IP rights. In fact, one of the powers explicitly given Congress in the Constitution is "To promote the Progress of Science and useful Arts, by securing for limited Times to Authors and Inventors the exclusive Right to their respective Writings and Discoveries." In recent years, however, many observers have raised concerns about the U.S. patent system. For example, the Federal Trade Commission (FTC 2003) describes concerns that the patent system has failed to keep up with the challenges posed by the growth of the knowledge-based economy. Similarly, the National Academy of Science (NRC 2004) describes unease among academics and practitioners that "the escalation in the number of patents, possibly encouraged by a lowering of the threshold to their

[3] President Lincoln was himself an inventor. He was granted patent no. 6469 in 1849 for a flotation system for lifting riverboats stuck on sandbars.

acquisition, was creating thickets of rights that could impede innovation." Shapiro (2008) sees the core problem as being that, in some circumstances, "the patent system predictably provides excessive rewards to patent holders." The opportunity for excessive returns can arise when patents are issued for technologies that are not genuinely novel or when a patent covers a small component of a complex product that allows the patent's owner to extract royalties disproportionate to the incremental value of the component. Some empirical evidence suggests that, at least in certain industries, greater patenting activity has in fact led to *reduced* R&D intensity (Hunt and Bessen 2004).

To address concerns about the performance of the patent system, President Obama, on September 16, 2011, signed into law the America Invents Act, the most significant reform of U.S. patent law since 1952. By allowing third parties to provide the patent office with additional information that may be helpful in assessing the novelty of an invention for which a patent application has been filed, the new law will reduce the number of improperly issued patents and thus increase "patent quality." The law will also reduce unnecessary litigation by creating new ways of resolving patent disputes more quickly and cheaply, allowing inventors to invest with more confidence in the validity of their IP rights while reducing the drag on innovation caused by improperly granted patents. The law will also reduce wait times for patent applicants by giving the U.S. Patent and Trademark Office more resources to reduce the backlog of applications and by creating a "fast-track option" for time-sensitive patent applications such as those from fast-growing startups or entrepreneurs seeking venture capital. Last, the new law will harmonize the American patent system with patent systems in the rest of the world by adopting a "first inventor to file" system. This change will make the U.S. system more efficient and predictable, allowing innovative entrepreneurs to market their products more easily in the United States while simultaneously exporting them abroad.

Private and Public Investments in R&D

R&D is a critical driver of innovation. Investments aimed at creating new knowledge or applying existing knowledge in new ways are often a necessary precursor to developing new or improved products or processes or entire new industries. Although innovative activities extend far beyond conventional R&D, and innovations arise in industries that perform little R&D as such, investing in R&D is generally an important element of innovative activity.

A large body of research confirms that investments in R&D increase productivity growth (CBO 2005). Other research demonstrates that the social returns to R&D investment are generally substantially greater than

the private returns. For example, Nordhaus (2004) concludes that "only a minuscule fraction of the social returns from technological advances over the 1948–2001 period was captured by producers, indicating that most of the benefits of technological change are passed on to consumers." (See also Hall, Mairesse, and Mohnen 2009; Bloom, Schankerman, and Van Reenen 2010; and Jones and Williams 1998.) These findings support the conclusion that R&D investments often have important positive spillover effects that prevent private firms from fully capturing the benefits of their innovations, thus giving them inadequate incentives to invest in R&D. In addition, Hall (2002) finds evidence that capital market imperfections may lead to underinvestment in R&D even in the absence of these spillovers. In short, economics research provides persuasive support for a robust government role in promoting R&D.

The United States is a world leader in R&D investments. With an estimated $400 billion in public and private expenditures in 2009, the United States invested more in R&D than China, Japan, and Germany combined. Moreover, R&D spending as a share of the U.S. economy has been increasing in recent years, with the ratio of R&D spending to GDP reaching nearly 2.9 percent in 2009, the highest since the 1960s. During that interval, however, the composition of U.S. R&D spending shifted dramatically. During the 1950s and 1960s, the majority of total R&D expenditures was federally funded; today nonfederal sources predominate. Private industry investments have consistently accounted for about 90 percent of all nonfederal R&D expenditures.

Despite the increasing role of private-sector investment in R&D, public support for R&D remains critically important, particularly in basic research, which aims to expand scientific knowledge and thus does not generally have immediate commercial applications. Private firms can thus find it especially difficult to capture the benefits that stem from this research, and the positive spillover effects of basic research can be especially large. For example, NSF-funded basic research into the principle of nuclear magnetic resonance ultimately led to the development of magnetic resonance imaging (MRI) machines, a medical imaging technology that has significantly improved diagnosis for cancer and other conditions. Not surprisingly, the Federal Government is a strong supporter of basic research. In 2008, while the Federal Government accounted for only 15 percent of U.S. development expenditures and less than one-third of applied research expenditures, it accounted for nearly 60 percent of the Nation's basic research expenditures.

Overall, the Federal Government provides substantial support for R&D. In 2009, when the Recovery Act helped Federal R&D spending reach 1.18 percent of GDP, the U.S. Government invested a greater share of GDP

in R&D than did the government of any other OECD country. Even in other years, the U.S. Government's R&D investments relative to GDP have substantially exceeded the OECD average. Although this largely reflects U.S. dominance in military R&D (national defense has historically accounted for more than half of Federal R&D expenditures), many defense-related innovations ultimately have significant benefits in the private sector. Research into communications networks by the Defense Advanced Research Projects Agency, for example, ultimately led to the emergence of the Internet.

Recognizing the importance of R&D for innovation, in April 2009, the President set the goal of devoting more than 3 percent of GDP to R&D, both public and private—a share that surpasses the record of almost 2.9 percent set in 1964 at the height of the space race. In its effort to reach this goal, the Administration has supported large increases in Federal R&D funding. The Recovery Act's investment of $18.3 billion in research funding was part of the largest annual increase in R&D funding in U.S. history. The President's Fiscal Year 2013 Budget has proposed additional support for science and basic research, making progress toward the goal of doubling funding for three key basic research agencies—the National Science Foundation, the Office of Science in the Department of Energy, and the National Institute of Standards and Technology. A particular success story is the Small Business Innovation Research (SBIR) and Small Business Technology Transfer (SBTT) programs, competitive programs that provide about $2.5 billion annually to the most promising research projects at small firms. From 2002 to 2006, about one-fourth of the "top 100" innovations selected by *R&D Magazine* came from companies that had received an SBIR grant at some point in their history. Recognizing the importance of continuing these successes, on December 31, 2011, President Obama signed a bill reauthorizing the SBIR and SBTT programs for the next six years.

In addition to direct Federal funding for R&D, the Administration has promoted incentives to support private R&D investment. The Research and Experimentation tax credit, for example, enacted in 1981, provides a tax credit based on qualified research expenses to encourage businesses to increase their investments. Subsidizing this activity through the tax system allows the private sector, rather than the government, to choose the research projects and the method for conducting the research. Recent studies show that the credit is a cost-effective way to encourage research spending (U.S. Treasury 2011). On September 8, 2010, the President proposed to expand and simplify the credit and to make it permanent; that proposal is also included in the President's FY 2013 Budget. The proposal will further enhance private firms' incentives to invest in research and will provide

businesses with assurance that the credit will be available for the duration of long-term research projects.

Commercialization

An important stage in the process of innovation is commercialization of new technologies. New inventions and new knowledge alone will have little effect on economic welfare unless they are converted into marketable products or processes that change how firms do business. One obstacle to realizing the economic benefits of innovation is the difficulty in transferring new ideas from universities and Federal laboratories to the marketplace. For example, recent empirical studies point to substantial frictions attributable to licensing costs and show large gains in innovation when these frictions are reduced (Williams 2010). Other researchers have found that universities often adopt technology transfer policies that constrain the volume of innovations brought into the marketplace (Litan, Mitchell, and Reddy 2007).

As the President announced in January 2011, one of the goals of the Administration's "Startup America" campaign is to foster innovation by increasing the rate of technology transfer. Since then, the Administration has announced a number of initiatives in support of this goal. In October 2011, the President issued a Presidential Memorandum directing the heads of Executive departments and agencies to take action to accelerate technology transfer and commercialization of Federal research in support of high-growth businesses. The National Center for Advancing Translational Sciences at the National Institutes of Health assists biomedical entrepreneurs by identifying barriers to commercialization and speeding development of new drugs and diagnostics. The Administration's National Bioeconomy Blueprint lays out a number of steps designed to advance biological research innovations, including reforms to speed commercialization and open new markets. The NSF's Innovation Corps program is a public-private partnership that will connect NSF-funded researchers with private-sector mentors who will help to transform the results of scientific research into commercially successful technologies. The Department of Energy (DOE) launched a program called "America's Next Top Energy Innovator," which offers startup companies low-cost and streamlined procedures for licensing new energy technologies patented by DOE labs. Together, the Administration's "lab-to-market" initiatives will encourage universities and government research centers to streamline their technology transfer procedures, support additional government-industry collaboration, and encourage the commercialization of novel technologies flowing from research programs—in short, they will facilitate the commercialization phase of the process of innovation.

Wireless Broadband and Spectrum Policy

Information and communication technology (ICT) is vitally important to the U.S. economy. A large body of research has linked economic growth in recent decades with ICT expansion. For example, Roller and Waverman (2001) estimate that one-third of the growth in per capita GDP in 21 developed economies from 1970 to 1990 is attributable to investments in telecommunications infrastructure. Similarly, Bloom, Sadun, and van Reenen (2007) note that the great majority of growth in U.S. productivity since the mid-1990s has been in sectors that either intensively use or produce information technologies.[4]

Wireless broadband is a form of ICT that can transform many different areas of the American economy by providing a platform for innovation, in areas ranging from media-rich consumer products to health care and education technologies. Much of the investment necessary to realize the potential of wireless broadband will come from the private sector. According to the Census Bureau, total capital spending by wireless telecommunications carriers has exceeded $20 billion in each year since 2000 (U.S. Census Bureau 2011). Public support is necessary in some important areas, including developing a nationwide wireless broadband network for public safety and extending wireless broadband services into rural communities, both of which are discussed in this chapter in the section on infrastructure. Another important way that the government can help to support the growth of wireless broadband is by making more spectrum available, both for licensed and unlicensed use. With the proliferation of smartphones, tablets, and other mobile devices with Internet access, mobile data traffic has been growing tremendously, more than doubling between 2009 and 2010, and industry forecasters expect data traffic to continue to grow rapidly (Cisco 2011). To accommodate this surging demand, wireless carriers will need access to additional spectrum.

In early 2011, President Obama introduced his National Wireless Initiative. The proposal aims to nearly double the spectrum available for wireless broadband in the next 10 years by freeing up 500 megahertz (MHz) of spectrum currently allocated to other uses. Some of this spectrum will be shifted away from Federal Government uses, in part by finding ways to make more efficient use of the remaining Federal and shared spectrum. Any changes in the use of Federal spectrum will be designed to ensure that there is no harmful interference with public safety needs or other critical public uses of the spectrum. Doubling the spectrum for wireless broadband will

[4] Jorgenson et al. (2008) estimate that ICT accounted for 59 percent of productivity growth during 1995–2000 and 38 percent during 2000–2006. Most recently, Brynjolfsson and Saunders (2010) conclude that most U.S. productivity growth since 1995 can be attributed to ICT.

also require changes in commercially licensed spectrum. Shifting to wireless broadband a portion of the spectrum now licensed for over-the-air television broadcasting will yield substantial economic benefits. To ensure that commercially held spectrum is reallocated efficiently and that the economic benefits are widely shared, the Administration supports using "voluntary incentive auctions" to guide the reallocation. These auctions will allow existing licensees to receive a portion of the auction proceeds in exchange for voluntarily making their spectrum available for wireless broadband. The auctions will also generate substantial revenues for the U.S. Treasury, providing support for important goals, including deficit reduction, R&D for emerging wireless technologies, and a nationwide interoperable wireless broadband network for public safety.

Clean & Secure Energy

In his State of the Union address, President Obama, noted that, "This country needs an all-out, all-of-the-above strategy that develops every available source of American energy. A strategy that's cleaner, cheaper, and full of new jobs." The President has outlined goals that will set the United States on a path toward lowering its dependence on oil and developing cleaner domestic energy sources that reduce emissions of air pollutants. Those include goals to continue focusing on increasing responsible domestic oil and gas production, to reduce foreign oil imports by a third by 2025, and to increase the share of electricity generated from clean energy sources—including nuclear power, natural gas, clean coal, and renewables like wind and solar—to 80 percent by 2035.

The President has outlined a *Blueprint for a Secure Energy Future* to guide the Nation's transition to a clean and secure energy economy. While the market provides key signals that greatly influence energy production and consumption decisions, energy markets are subject to market failures, so the government has an important role to play in guiding the mix of energy supplies and uses that is best for the Nation. The government also has a role to play in increasing energy security, reducing air pollution, promoting clean energy through investments in innovation and infrastructure, and establishing rules of the road that promote a cleaner and more secure energy future.

Enhancing Energy Security

The short-run demand for energy is relatively inelastic, so consumers will bear the brunt of sudden, unexpected energy supply disruptions in the form of price increases, causing them to reduce their consumption of other goods and services, or reduce savings. Elevated global energy prices can,

in turn, slow economic growth. Promoting the development of alternative energies and energy-efficient technologies reduces the economy's vulnerability to international energy supply shocks and improves energy security. Oil consumption per thousand dollars of real GDP has fallen by about half since 1980 (from almost one barrel per thousand dollars of GDP in 1980 to about 0.5 barrel per thousand dollars of GDP in 2010). Despite progress in reducing the "petroleum intensity" of the economy, vulnerability to increases in the global market price of crude oil remains. We can improve energy security by lowering demand for petroleum and by increasing the supply of domestic conventional and alternative energy.

Reducing Demand

During the past year, the Administration has pursued a course that reduces demand for petroleum. In November, EPA and DOT proposed new fuel economy standards for vehicle model years 2017–2025, building on the successful programs for the 2011 and 2012–2016 model years. These standards will save consumers money at the pump, dramatically reduce the Nation's dependence on oil, and increase investment in new technologies and new manufacturing here in the United States. Under the proposed rules, fuel economy standards from the DOT, greenhouse gas (GHG) emission standards from the EPA, and State of California regulations will be harmonized and auto companies will be able to rely on well-defined regulatory targets to help steer their investments in producing advanced vehicles. Annualized costs of the rule are expected to be between $6.4 billion and $10.6 billion; annualized fuel savings are expected to range between $20.3 billion and $26.7 billion (2009 dollars). Additional annualized benefits from improved health, greater energy security, and lower GHG emissions are expected to range between $5.4 billion and $6.4 billion. Taken together, the fuel economy standards proposed for model years 2011–2025 are projected to reduce oil consumption by over 2.2 million barrels per day by 2025, and save consumers $1.7 trillion in fuel costs.

The President has also proposed a new tax incentive to offset half of the incremental cost of dedicated alternative-fuel commercial vehicles, such as natural gas and electric trucks, for a five-year period. In addition, the President has proposed transforming the individual tax credit for consumers who purchase advanced vehicles into a rebate.

Increasing Domestic Energy Supplies

The Nation has pursued strategies to safely increase domestic energy sources. As part of this focus, the President is committed to advancing the responsible production of domestic oil and natural gas resources. Thanks

to higher domestic production and lower imports, dependence on foreign oil is being reduced. In 2010, for the first time in over a decade, the United States relied on net imports for less than half of the oil we consumed; in 2011, import dependence declined even further, to 45 percent. Since 2007, the United States has been the leading natural gas producer in the world.

To help ensure safe and responsible development of abundant natural gas resources, the Administration is taking a number of steps, including: exploring home grown technologies and methods to improve safety and environmental performance of shale gas production; encouraging greater use of natural gas in transportation; and requiring disclosure of chemicals used in hydraulic fracturing on public lands. As Box 8-1 describes, the development of unconventional oil and gas deposits across the United States illustrates how American enterprise and innovation in horizontal drilling and hydraulic fracturing, combined with government-supported research, have unlocked vast new domestic oil and gas resources.

The United States has also increased the amount of ethanol and biodiesel blended into the nation's fuel supply. In 2011, ethanol and biodiesel production in the United States were estimated by the U.S. Energy Information Administration (EIA) to be roughly 14 billion gallons and 920 million gallons, respectively (EIA 2012). That represented about 10 percent of U.S. gasoline demand and 2 percent of diesel demand for 2011. In March 2011, the President set the goal of breaking ground on at least four commercial-scale cellulosic or advanced bio-refineries over the next two years, and we are on track to exceed that goal. In addition, the Administration announced a partnership between the Departments of Agriculture, Energy and the Navy to invest in multiple domestic commercial or pre-commercial scale bio-refineries to produce advanced "drop-in" biofuels, substitutes for diesel and jet fuel.

Reducing Emissions

The Administration has taken historic steps to address air pollution from stationary sources such as aging coal-fired power plants. The Mercury and Air Toxics Standard (MATS) regulation announced by the EPA in December, for example, will reduce emissions of sulfur dioxide, mercury and other toxic air pollution and generate between $27 billion and $80 billion in net benefits annually by improving people's health.

In addition, to create a market for innovative technologies that will encourage the deployment of clean energy and the benefits that come with it, such as reduced emissions of air pollutants and greenhouse gases, the President has proposed a Clean Energy Standard (CES).

A CES works by giving electric power plants clean energy credits for electricity they generate from clean energy. Utilities that serve retail customers are responsible for making sure they have enough clean energy credits to meet their target. Utilities that generate more clean energy than needed to meet their target can bank their extra credits for later use, or sell them to other companies. Under the President's proposal, the target would increase over time, so that by 2035, 80 percent of the country's electricity would be generated from clean sources. This flexible approach would harness private-sector incentives to minimize the cost of generating electricity from clean energy sources.

Because of cleaner power plants, greater use of alternative fuels, and more energy-efficient vehicles, buildings, and appliances, EIA (2012) expects per capita emissions of carbon dioxide in the United States to fall over time, by an average of 0.8 percent a year between 2010 and 2035.

Supporting Clean Energy R&D and Infrastructure

Public investments in innovation and infrastructure are critical to solving the twin objectives of increasing energy security and reducing GHG emissions. Private-sector investment in energy R&D and infrastructure will be less than optimal because the positive externalities from such investments prevent private firms from fully capturing the benefits. Support for innovation is a key piece of the *Blueprint* strategy, which involves creating markets for clean technologies that are ready to deploy and funding cutting-edge research to deliver the next generation of technologies. In addition, investments in modernizing the energy infrastructure with advanced technologies will help to increase efficiency and reduce waste. Innovation and adoption of new technologies will be critical to improving energy efficiency and shifting the Nation's energy use toward low-carbon energy generation.

Among the DOE offices that provide support for clean energy innovation is the Advanced Research Projects Agency-Energy (ARPA-E), an organization modeled after the Defense Advanced Research Projects Agency. ARPA-E provides funds to develop advanced energy technologies that reduce energy-related emissions and increase energy efficiency, focusing on transformational energy research that the private sector by itself is unlikely to support. The Obama Administration funded ARPA-E for the first time with $400 million as part of the Recovery Act. This funding, along with subsequent appropriations, has been used to support about 180 projects, including technologies for plug-in electric vehicles, batteries that convert wind power into a steady power source, and microorganisms that produce liquid biofuels from sunlight and carbon dioxide. The President's Fiscal Year 2013 Budget proposes $350 million in new funding for ARPA-E to continue

Box 8-1: Developing Domestic Energy: Shale Gas and Shale Oil

Shale gas and shale oil (also known as "tight" oil) are deposits trapped inside formations of fine-grained sedimentary rocks, or shale. As recently as a decade ago many of these deposits were viewed as uneconomical to extract. Now they are being profitably extracted, leading to a boom in production from these unconventional oil and gas deposits.

The President has been clear about the importance of domestic oil and gas production, including the central role responsible natural gas development will play in our energy future, increasing energy independence, and supporting jobs.

The percent of new wells directed to shale gas and oil deposits surged from 13 percent in 2005 to 57 percent in 2011. That dramatic increase is in large part due to rising energy prices in the early 2000s, which made it profitable for oil and gas companies to pursue higher cost reserves. But it is also due in part to R&D investments made by the Department of Energy (DOE). Between 1978 and 1992, the DOE invested about $137 million in the Eastern Gas Shale program, which helped develop and demonstrate directional and horizontal drilling technology.

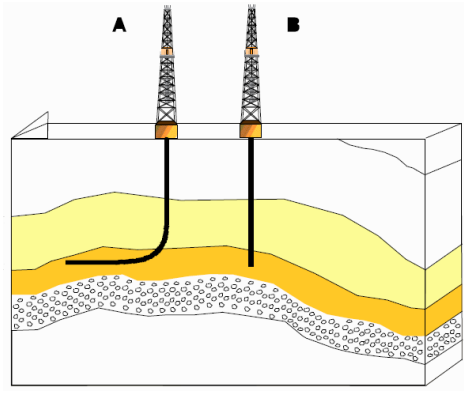
Horizontal drilling allows multiple wells to be completed from one drilling pad by drilling vertically for several thousand feet and then drilling horizontally. Hydraulic fracturing pumps water, chemicals and sand into the well to fracture the surrounding rock, releasing trapped natural gas and oil, allowing more gas and oil to be captured (see figure). From 2006 through 2010 the average annual growth rate of shale gas production was 48 percent. By 2035 shale gas is expected to make up 49 percent of total U.S. natural gas production, up from 23 percent in 2010 (EIA 2012). Increased supply has caused wholesale natural gas prices to fall more than 75 percent from their peak in October 2005 through October 2011. This led to a 67 percent drop in prices charged for natural gas used to generate electricity and a 34 percent decline in residential natural gas prices.

Domestic oil production also grew in 2009 and 2010, in part due to horizontal drilling methods. That growth helped improve America's energy security. We reduced our imports of crude oil, from 10.1 million barrels per day in 2005 to an estimated 8.9 million barrels per day in 2011. EIA (2012) projects that domestic oil production will continue to increase through 2020. We are also exporting more refined petroleum products than ever: between the first half of 2009 and the first half of 2011, exports of mineral fuels and oils jumped 150 percent, an increase valued at more than $35 billion (see Chapter 5). In addition, the United States is at the forefront of exporting extraction technologies and related services to other countries interested in tapping their own unconventional oil and gas reserves.

This expansion of natural gas and oil production has also supported jobs for thousands of Americans. Bureau of Labor Statistics (BLS) data show that oil and gas extraction and drilling services jobs have grown by 100,000 between 2005 and 2010, with much of that increase tied to horizontal drilling for shale gas and oil. The industry also indirectly supports many more jobs, including jobs associated with the transportation, processing, and distribution of oil and natural gas products. Furthermore, downstream industries, such as the chemical and plastics sectors that use natural gas as an important input, benefit from the expanded supply of natural gas.

Such tremendous growth also comes with the responsibility to develop these new resources safely. A number of concerns have been raised regarding the potential adverse environmental impacts associated with current shale gas extraction practices, particularly the use of hydraulic fracturing. The Obama Administration is taking a number of steps to ensure that the United States can realize the economic benefits of its natural gas resources in a an environmentally responsible way. An important part of this effort consists of targeted research coordinated between the DOE, the Department of the Interior, and the Environmental Protection Agency to assess and address potential impacts of natural gas and oil development using hydraulic fracturing and to identify innovative ways to reduce adverse environmental impacts. For example, the DOE is actively involved in research exploring improved methods to treat the water used in shale gas extraction so it can be reused or disposed of safely. The Administration is committed to ensuring that natural gas and oil extraction will be pursued in a prudent manner that is safe for the environment.

Horizontal Well (A) vs. Vertical Well (B)



Source: EIA (1993).

to support breakthrough clean energy research in areas such as solar energy, energy storage, carbon capture and storage, and advanced biofuels.

An important part of the effort to transition to a clean energy future is the "SunShot Initiative" announced by the DOE in February 2011. This initiative supports innovation to reduce the cost of solar energy by 75 percent by 2020, making unsubsidized solar energy cost-competitive with other forms of energy. Achieving the goal will require major innovations in the ways solar technologies are conceived, designed, manufactured, and installed. SunShot is investing in solar technology and manufacturing improvements and working to reduce installation and permitting costs. According to DOE (2011) analysis, by reducing the cost of solar electricity to about six cents per kilowatt hour, SunShot has the potential to increase the share of electricity generation from solar photovoltaics to 15 percent by 2030.

As the United States transitions to a clean energy future, an important way to improve energy efficiency, reliability, and security is to upgrade the electricity transmission and distribution infrastructure to make greater use of advanced technology and to incorporate real-time communications, monitoring, and control systems. Transforming the electricity infrastructure into a "smart grid" could lead to substantial cost savings and efficiencies, help avoid blackouts, and improve the integration of renewable energy sources on the grid. The Recovery Act included $4.5 billion in grid modernization investments, matched by contributions of more than $5.5 billion from the private sector. Building on these investments, the Administration announced a number of new initiatives to support the development and deployment of smart-grid technologies, including $250 million in loans to deploy smart-grid technology in rural areas under the Rural Utility Service. In June 2011, the White House released a report by the National Science and Technology Council, "A Policy Framework for the 21st Century Grid: Enabling Our Secure Energy Future," outlining policy recommendations that build on existing smart-grid investments to foster continued modernization of electricity infrastructure.

In addition to efforts to support smart grid development, the Administration has announced efforts to improve Federal coordination and ensure timely review of proposed renewable energy projects and transmission lines through the formation of two interagency Rapid Response Teams, one for transmission and one for renewables. The Rapid Response Team for Transmission is focused on seven pilot project transmission lines which cross through 12 states. These projects were selected from lists produced through independent stakeholder processes. When built, these seven pilot projects will help increase electric reliability and integrate renewable energy into the grid. The agencies participating in the Renewable Energy Rapid

Response Team have all made significant strides toward the deployment of renewable energy through the development of better government processes to issue permits for renewable energy projects.

Infrastructure

As emphasized, energy infrastructure is critical for developing our domestic clean energy potential. Infrastructure also includes transportation systems like roads, railways, ports and airports; information and communications networks; and schools, parks, and other public facilities. As economic activity grows, the infrastructure that supports it must grow as well. Moreover, physical infrastructure deteriorates over time and requires ongoing investment for maintenance. If investments to maintain, upgrade, and expand infrastructure do not keep pace with the growth in demand, the result is congestion: too many hours sitting in traffic or in an airplane stalled on the tarmac, too many dropped calls, slow Internet connections. Such disruptions impose substantial economic costs through wasted time and resources and diminished quality of life. As a result, efficient infrastructure investments can have a significant positive impact on economic welfare.

The State of the Nation's Infrastructure

The value of the U.S. transportation capital stock steadily increased from 2004 to 2009, reaching more than $6 trillion in 2009 (the most recently reported year). The greatest percentage increase in mileage for any mode of transportation from 2004 to 2009 was in light transit rail track, which increased by 24 percent, followed by commuter rail track, which increased by 10 percent. At the same time, the overall condition of many parts of the Nation's transportation infrastructure remained disappointing. In 2008, nearly 21 percent of urban interstate highways and 35 percent of urban collector roads were in poor or mediocre condition, according to the Bureau of Transportation Statistics. Moreover, in 2009 nearly 71,200 bridges—more than 10 percent of all U.S. bridges—were rated as structurally deficient.

The current disappointing state of transportation infrastructure is partly reflected in rising levels of congestion on many parts of the transportation system, particularly urban roadways. According to the Texas Traffic Institute's (TTI) *Urban Mobility Report*, traffic congestion in urban areas in 2010 accounted for 4.8 billion hours of travel delay and 1.9 billion gallons of wasted fuel, for an aggregate congestion cost of more than $100 billion, an increase of more than 25 percent over 2000 in constant (inflation-adjusted) dollars (Schrank, Lomax, and Eisele 2011). If current trends continue, TTI projects that the total cost of congestion in U.S. urban areas could grow by

a further 32 percent in real terms by 2015. These estimates likely understate the real effects of congestion on welfare because they do not take into account the reduction in quality of life that results from additional time spent commuting. Studies of how individuals experience the activities of daily life have found that commuting is among the least enjoyable and most stressful (Kahneman et al. 2004, Stutzer and Frey 2004).

The U.S. electricity grid is also showing signs of strain, with investment in capacity generally lagging behind growth in demand. According to the DOE (2008), growth in peak demand for electricity has exceeded transmission growth by almost 25 percent every year since 1982. Power outages and interruptions have become more frequent and are now affecting more consumers. The DOE reported that 41 percent more outages affected 50,000 or more consumers in the second half of the 1990s than in the first half, and the average outage affected 15 percent more consumers. By 2008, power outages and interruptions cost Americans an estimated $150 billion each year.

Broadband is another important category of infrastructure where the United States faces significant investment needs. Described by the Federal Communications Commission as "the great infrastructure challenge of the early 21st century" (FCC 2010), broadband's growth over the past decade has been substantial. Thanks to significant investments by telecommunications and cable companies, 95 percent of the U.S. population had access to wired broadband service in 2010, and industry analysts project that by 2013, wireless providers will offer such service to about 94 percent of the population. (Atkinson et al. 2011). At the same time, many households, particularly in rural areas, continue to have Internet access only at much slower speeds. As discussed, perhaps the most significant challenge to the Nation's broadband infrastructure is the threat of growing congestion on wireless networks.

Overall, evidence is growing that the United States has been underinvesting in many kinds of infrastructure. For example, the Nation invests annually approximately 2 percent of GDP on infrastructure, compared with 9 percent and 5 percent, respectively, for China and Europe. In addition, compared with other OECD countries, Americans are relatively dissatisfied with their local public infrastructure systems, according to the Gallup World Poll. Americans' satisfaction with public transit ranks 25th out of 32 OECD nations, and satisfaction with roads and highways ranks 17th out of 32. Many observers, including the American Society of Civil Engineers (2009), have concluded that the United States faces a substantial need for infrastructure investment over the next five years. Although the optimal level of infrastructure investment is difficult to quantify precisely, the evidence strongly suggests that the United States has not been investing adequately to meet future infrastructure needs.

Government and Private Sector Roles in Infrastructure

In the United States some kinds of infrastructure, including most roadways and public transit systems, are typically owned and financed by government; other kinds, such as freight railways and telecommunications networks, are largely privately owned. In part, these patterns of ownership reflect historical accident. In choosing how much public support for infrastructure to provide and how to finance it, the United States, like other nations, faces questions about how best to balance the roles of the public and private sectors in infrastructure investment. Two key economic principles are whether it is costly or difficult for a private owner or investor to earn a return by monetizing access to the network, through tolls or user fees, and whether important positive spillover benefits from infrastructure investment would prevent private investors from fully capturing the overall economic benefit, even if there were a dedicated revenue stream from users.

The most important potential positive spillover effect is that many infrastructure investments improve economic efficiency, increase productivity, and promote rapid economic growth. Through these effects, as a large body of research has shown, investments in infrastructure can substantially improve the long-run performance of an economy. For example, Munnell (1992) reviews the evidence on infrastructure investment and economic growth and concludes that, "in addition to providing immediate economic stimulus, public infrastructure investment has a significant positive effect on output and growth." Gramlich's (1994) review of the same research cautions that the rates of return on investments vary widely across different types of infrastructure and highlights the need for policies that direct public investment toward projects with the highest social return. More recent studies have found further evidence that public infrastructure investment often offers considerable returns, in some cases higher than those from private capital investment. This research is reviewed in a U.S. Treasury-CEA report (2010).

In addition to their long-run benefits on economic growth and productivity, investments in infrastructure can also provide short-run benefits during times when economic resources are underutilized, by supporting employment in construction and in materials production. These short-run effects depend on the state of the overall economy. When the economy is operating at or close to its full potential, the new employment generated by infrastructure projects generally requires diverting workers from other productive activities, and the expenditure of public funds may similarly divert funds from other investment opportunities. Certain infrastructure investments may still be justified during such times, but the opportunity costs of

diverting economic resources from other activities reduce the net benefits of such investments.

By contrast, today the economy is gradually recovering from the most serious economic crisis since the Great Depression and is operating significantly below its full potential, with unemployment still unacceptably high. In 2011, over 1.8 million workers in the construction industry were jobless, with an industry unemployment rate of 16.4 percent. In these circumstances, public infrastructure projects create net jobs for workers. With excess capacity widely available in the economy, increased public spending on construction materials and increased private spending by newly hired workers are unlikely to divert goods or materials from other uses. Similarly, with interest rates exceptionally low, there is little risk that Federal investment will crowd out private investment, and more infrastructure investments will yield a positive rate of return. Moreover, State and local governments, which typically fund a significant portion of infrastructure spending, have been forced to cut back on spending because of revenue shortfalls since the recession of 2007–09. Recent macroeconomic research confirms the intuition that the expansionary effect of Federal investment spending is likely to be significantly greater during times of substantial slack in the economy. For example, Auerbach and Gorodnichenko (2010) find that expansionary fiscal policy is substantially more effective during recessions than during expansions. Overall, with so many resources sitting idle, the opportunity costs of using those resources for infrastructure investment are greatly reduced. Moreover, postponing necessary infrastructure investments until after the economy has rebounded would have the undesirable effect of occupying productive resources just when the private sector needs them most.

Financing Infrastructure Investments

Government funding for infrastructure draws on a number of different sources, including Federal disbursements of Highway Trust Fund revenues and State and local issues of municipal bonds. Recent years have seen increased interest in alternative financing mechanisms that may expand the pool of available capital and improve the efficiency of project selection. A common theme in these alternative approaches is the goal of attracting more private capital for direct or indirect investment in transportation infrastructure. Increased reliance on the private sector to finance transportation infrastructure investments can help increase funding for those investments and may also improve the efficiency of project selection and drive greater returns on investment. For example, to attract private financing, many projects incorporate a dedicated revenue stream, often from user fees or other forms of usage-based pricing. Because these revenue streams

link investment returns directly to user demand, they can help to guide capital toward the most efficient projects. In general, innovative financing mechanisms can engage the private sector in infrastructure investments with important public benefits. In particular, this chapter considers three innovative approaches to private-sector engagement: public-private partnerships, particularly in the area of rail freight; Build America Bonds (BABs) as an alternative to municipal bonds that can attract new sources of private funding into the market for financing infrastructure projects; and a National Infrastructure Bank that has the potential to leverage private capital into projects of national significance.

Public-Private Partnerships. In the United States, most investment in freight railway infrastructure is privately financed, because it is largely owned by the rail carriers themselves. However, even in a network based on private ownership, important public benefits can be realized through investments that improve the flow of freight across the railway network. The benefits of diverting freight efficiently from trucks to rails, for example, include reduced highway congestion, greater safety, and reduced pollution. Public-private partnerships between State and Federal agencies and the rail carriers can be an efficient way to promote such investments. For example, the Chicago Region Environmental and Transportation Efficiency program is a public-private partnership between the U.S. Department of Transportation, the State of Illinois, the City of Chicago, Metra commuter rail, and Class I railroad companies. The partnership, formed to develop and implement a set of multimodal infrastructure improvements to untangle congestion choke points in the Chicago transportation hub, involves significant financial cooperation between the private railroad industry and public government entities.

Build America Bonds. Introduced in 2009, BABs are taxable bonds for which the U.S. Treasury Department pays a direct subsidy to the issuer to offset borrowing costs for public capital infrastructure projects. These bonds can function as an attractive alternative to municipal bonds, which deliver a borrowing subsidy only indirectly through the Federal tax exemption to investors for interest earnings. BABs appeal to a broader class of investors than tax-exempt municipal bonds, including nonprofits, pension funds, and many other institutional investors. Since the inception of the program in April 2009, BABs have had a very strong reception from both issuers and investors. They have supported more than $181 billion of financing, in 2,275 transactions in all 50 states, the District of Columbia, and two territories, for new public capital infrastructure projects such as schools, bridges, and hospitals. An empirical study by the Treasury Department (2011) found that State and local governments that issued BABs realized considerable savings

relative to the cost of issuing tax-exempt bonds. The study also found that expanding the BABs program would lead to continued savings on borrowing costs for State and local governments. Although the initial program expired at the end of December 2010, the President's Fiscal Year 2013 Budget has proposed extending the program for two years at a subsidy rate of 30 percent and extending it permanently thereafter at a revenue-neutral subsidy rate of 28 percent. The Administration has also proposed expanding the program to include a broader range of eligible municipal projects.

National Infrastructure Bank. Another new approach to increasing private-sector participation in infrastructure investment is a National Infrastructure Bank, as President Obama has proposed as part of the American Jobs Act. The proposed bank would help increase overall investment in infrastructure by attracting private capital to co-invest in specific infrastructure projects and would help improve the efficiency of infrastructure investment by relying on a merit-based selection process for projects. To ensure substantial leverage of private capital, the bank would finance no more than 50 percent of the total costs of any project. It would fill in an important gap in the Nation's infrastructure funding system by focusing on projects of national or regional significance, whose effects cross over state and jurisdictional lines. Such projects are often at a disadvantage under current financing mechanisms, including state-level infrastructure banks and bonds issued by State and local governments. As a result, the National Infrastructure Bank would be a valuable complement to existing sources of funding and would improve the efficiency of U.S. infrastructure investment.

Recent and Current Federal Infrastructure Initiatives

Infrastructure investment has been an important priority throughout the Obama Administration. As discussed above, the modernization of the electricity grid is a key element of the effort to transition to a clean energy future. This subsection reviews some of the Administration's other recent and current initiatives to support infrastructure investment.

Transportation. The Recovery Act of 2009 provided over $48 billion to fund transportation infrastructure investments. In 2010, the Federal Highway Administration announced that it had finished obligating more than $26 billion of that amount for 12,000 road, highway, and bridge projects, and in June 2010, President Obama visited Columbus, Ohio, to commemorate the breaking of ground on the 10,000th such project. The Recovery Act also provided funds for investments in the Nation's air and sea transportation infrastructure, including $1.3 billion to construct new runways and improve air traffic control facilities and equipment, as well as more than $18 billion to support transit and high-speed rail. Many of these

and other recently completed transportation infrastructure investments have already produced substantial economic benefits for the American people, including increased flows of traffic in congested areas, improved highway safety, expansion of public transit service into new communities, and rehabilitation and maintenance of aging infrastructure.

Despite these substantial achievements, there is still a pressing need to revitalize America's infrastructure networks. Recognizing this need, President Obama has proposed $50 billion in immediate investments in transportation infrastructure as part of the American Jobs Act. The proposal includes investments to speed up the permitting process, to make highways safer and more efficient, to repair and modernize public transit systems, to improve intercity passenger rail service and airports, to develop high-speed rail corridors, to support innovative multi-modal transportation programs, and to modernize the air traffic system by investing in the Next Generation Air Transportation System, or NextGen. The President also supports a robust renewal of surface transportation programs, now scheduled to expire on March 31, 2012, to keep existing and planned transportation projects moving forward.

Broadband. The Recovery Act provided $7.2 billion to upgrade the Nation's broadband infrastructure, including $4.7 billion for broadband infrastructure programs at the Department of Commerce's National Telecommunications and Information Administration (NTIA) and $2.5 billion for the Department of Agriculture's Rural Utilities Service (RUS) to expand broadband access in rural areas. These two programs together received more than 3,800 applications requesting more than $52 billion in support for potential projects in all 50 states and territories. When the final awards were announced in September 2010, NTIA had awarded approximately $4 billion for 233 projects throughout the country. The funds will support the construction or upgrade of approximately 120,000 miles of broadband infrastructure and will improve broadband access for approximately 24,000 community institutions, including schools, libraries, and health care facilities. In addition, RUS has awarded more than $3.5 billion in grants and loans for 320 broadband projects, which will provide broadband access for 2.8 million households and 364,000 businesses in rural areas.

As part of the National Wireless Initiative, the President has called for investment in a state-of-the-art nationwide wireless broadband network for public safety communications. Developing and deploying such a system would help enable interoperability at the national level, making first responders more effective when they are called on to cross jurisdictional lines. An interoperable network would also reduce the costs of the assorted interoperability measures now being used, ranging from swapping radios to

using Internet-based gateways to patch together noninteroperable systems. Moreover, deploying a single nationwide network would realize important scale economies, eliminating duplicative operating and maintenance costs and enabling public safety entities to obtain commercially supplied devices and equipment at substantially lower cost than they can today. Finally, with clear, nationwide standards that help make public safety communication systems interoperable across jurisdictions and vendors, software and hardware developers will find it more economical to invest in innovative public safety devices and applications, further enhancing the effectiveness of first responders.

Conclusion

Through smart regulation, innovation, promotion of clean domestic energy, and public investment, the Federal Government helps Americans every day, improving safety and health, laying the groundwork for technological breakthroughs, and putting into place the infrastructure that facilitates commerce and travel and raises productivity. The benefits of these activities are not fully reflected in standard measures of economic activity such as GDP, but they do significantly improve the quality of life and our economy.

Jan Tinbergen (1976), the first winner of the Nobel Prize in economics, commented that, "progress in our understanding can only be based on our push for measurement of phenomena previously thought to be nonmeasurable." Spurred by the creation of new measurement techniques and the need to improve conventional measures of well-being, several recent official efforts have aimed at expanding the boundaries of measurement of the quality of life. As this year's *Economic Report of the President* suggests, further innovation and advances in measurement through improvements to traditional economic indicators and the development of new indicators of societal well-being will help bring about further improvements in the Nation's quality of life and the economy.