Scoring 50 Years of US Industrial Policy, 1970–2020

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1 Introduction

BRIEF HISTORY

Proponents of mobilizing US government support for domestic manufacturing—and creating a homegrown “industrial policy”—may not realize it, but they are channeling an approach first introduced in 1791 by Alexander Hamilton, the storied founding father and Treasury Secretary under President George Washington. While serving at Treasury, Hamilton formed a group of investors called the Society for Establishing Useful Manufactures (S.U.M.) to use the power of the Great Falls in the Passaic River near Paterson, New Jersey, to drive an industrial sector that would compete with Britain as a producer of manufactured goods for American consumers. The initial capitalization of S.U.M. was $500,000, a huge sum at the time.

Like much of what Hamilton wrought, the scheme was highly controversial. Hamilton’s archrival in American politics, Thomas Jefferson, did not see America’s future in expanding its industrial base but in supporting its agricultural backbone, which he felt was the moral as well as the economic center of the nation’s future, and he vehemently opposed government involvement in supporting an industrial policy. Through much of the 19th century, however, Hamilton’s view prevailed. The “American System” of Henry Clay, set up to compete with Britain after the War of 1812, consisted of high tariff walls, a central bank and, above all, government investment in “public improvements” like rails, canals, and roads to help industry get goods to customers—the very essence of an industrial policy that some analysts say was crucial to US economic development after the Civil War.

In the 20th century, the debate over the role of the federal government, and especially over tariffs and government spending, has gone back and forth. But by 2020, the US ideological pendulum appears to have swung back in favor of industrial policy for domestic manufacturing. The US-China trade war and COVID-19 prompted the Trump administration to launch both reshoring policies to bring US firms with Chinese outposts back to the United States, and subsidies to boost domestic production of medical equipment and assorted high-tech products.

When President Joseph R. Biden Jr. came into office he ordered a supply chain review report, and it calls for ambitious measures to strengthen the US supply chains of semiconductors, electric batteries, critical materials (e.g., rare earths), and pharmaceuticals. On June 8, 2021, the Senate passed the American Innovation and Competition Act, which includes $52 billion to boost domestic manufacturing of semiconductors and $200 billion for scientific and innovation research and development (R&D). Other legislation embracing industrial policy concepts has been introduced in Congress.

With President Biden in the White House and Democrats in control of the House and Senate, ambitious industrial policy proposals are being turned into law. The comeback of industrial policy in the United States does not signal an end to the debate, however. It is probably more urgent than ever to understand how and whether industrial policy has worked to strengthen the US economy. An examination of recent history provides useful context. In this collection of case...
studies, we present a thorough analysis and scorecard of leading US industrial policy initiatives since 1970, in an effort to assess what went right and what went wrong—and how the current initiatives might fare. These case studies can guide policymakers as they embark on what appears to be a major initiative in US government involvement in the economy, one that has broad but hardly universal political support.

DEFINITION AND GOALS OF INDUSTRIAL POLICY

First, we offer a definition and then a short summary of the US ideological cycle for employing industrial policy. Marcus Noland and Howard Pack (2003, 10) define “industrial policy as an effort by a government to change the sectoral structure of production toward sectors it believes offer greater prospects for accelerated growth than would be generated by a typical process of industrial evolution according to static comparative advantage.” Somewhat more simply, but more inclusively, we define industrial policy as government intervention against market forces to promote a favored firm or industry. Accelerated growth is one objective, but certainly not the only one. Tools of industrial policy include easy credit, direct and indirect subsidies, preferential taxes, and tariff and nontariff barriers.

Over the past half-century, the goals of industrial policy (as we define the term) have varied. In some episodes, the goal was to assist declining industries (e.g., steel, textiles and apparel), both to save jobs and to rescue firms. In others, the goal was to offset externalities (e.g., solar and wind energy), in particular to reduce carbon emissions. And in still other episodes, the goal was to promote US leadership in emerging technologies (e.g., semiconductors, communications).

The Trump administration responded to the COVID-19 national emergency with Operation Warp Speed, designed to accelerate the discovery and dissemination of effective vaccines. Looking forward, the Biden administration and Congress are seeking to ensure that the United States stays ahead of China in frontier technologies such as artificial intelligence, cyberspace, and electric vehicles. As well, robust supply chains are a fresh concern of government leaders, who fear (given experiences of the past 18 months) that private firms do not adequately consider systemic failures caused by pandemics, natural disasters, or foreign adversaries.

Our retrospective analysis is not focused on particular objectives but instead tries to distill lessons from industrial policy episodes that sought varied objectives over the past 50 years.

The definition of industrial policy could be stretched to cover broad government programs so widely accepted that they become part of the social fabric. In 19th century America, the post office, canals, rails, and land grant colleges would fit in that broad definition. In the mid-20th century, the national highway system and extensive electrical grids and gas pipelines would also fit. Such programs arguably accelerated US economic growth. This study, however, is confined to more narrowly targeted, and less widely accepted, government interventions that affect specific firms, industries, or R&D in pursuit of varied objectives, many of them only loosely connected to economic growth.
INTELLECTUAL DEBATES

Over the past half-century, industrial policy has stimulated recurring debates. Writing in the *Harvard Business Review* in 1982, a time when America felt threatened by Japanese industrial success, Robert Reich (1982) titled his essay “Why the U.S. Needs an Industrial Policy.” He argued that government can help US firms adapt to global competition in two ways: (1) by smoothing the movement of resources out of declining industries, and (2) by ensuring the availability of resources to promising sectors. In short, he envisioned an idealized role for government intervention, divorced from the push and pull of practical politics.

Our definition of industrial policy is not confined to Reich’s idealized conception. We evaluate several episodes that attempted to neither smooth decline nor channel resources to promising industries. Laura Tyson, in her 1992 book *Who’s Bashing Whom? Trade Conflict in High-Technology Industries*, examined America’s disputes with other countries—especially Japan—in the computer, semiconductor, electronics, and commercial aircraft industries. She argued that the United States should defend itself against damaging foreign practices but only by approaches that encourage competition, not with protectionist measures that thwart economic adjustment. Noland and Pack (2003) contended (despite the arguments of contemporary scholars) that industrial policy had a minor impact on economic growth in Asia. More recent empirical literature suggests that early studies of infant industries in developing economies may not fully capture the benefits and costs of industrial policy (Lane 2020).

Contrary to Reich and Tyson, other observers pointed skeptically to failed initiatives and government capture, a theme stressed by “public choice” economists, notably Gordon Tulloch and James Buchanan (1962). Skeptics usually define industrial policy to encompass a broad range of government intervention, not just episodes that attempt idealized objectives. Paul Krugman (1983) examined the US steel and semiconductor industries, two sectors that enjoyed government support in competition with Japan, and concluded that in neither instance could US policy be called a success.

For decades, during an era of liberalization that lasted from 1950 to 2000, US trade protection was captured by sunset industries, notably sugar and specialty agriculture (e.g., honey, lamb), apparel, ceramics, basic steel, and the merchant marine, among others. Several economists reported, with few exceptions, that industrial policy in Turkey, South Korea, and Japan was either negatively correlated with performance or not correlated at all (Krueger and Tuncer 1982, Harrison 1994, Lee 1996, Beason and Weinstein 1996, Lawrence and Weinstein 2001). Charles L. Schultze (1983), a leading American scholar and influential advisor to Democratic presidents, was a stout critic of US industrial policy.1

Contrasting with skeptical voices, 18th and 19th century literature is replete with rationales for government intervention. Alexander Hamilton is famous for, among other achievements, articulating the infant industry argument, later the

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1 Schultze effectively suppressed calls for industrial policy from Clyde Prestowitz, Robert Reich, and Robert Kuttner during the Carter presidency. Similar skepticism cannot be found among Democratic leaders today.
subject of a noted treatise by Friedrich List.\(^2\) Closely related, but advanced in the 20th century, is the argument that economies of scale may deter potential entrants and should be redressed by government measures to ensure a market of adequate size. During and after the Second World War, academic scholars focused on developing economies. The balanced growth model (Rosenstein-Rodan 1943, Nurkse 1952) observed that industries buy and sell from each other and their returns depend on the existence of complementary industries, calling for government coordination. Albert Hirschman (1958) advanced the thesis, urging targeted support on industries with strong industrial linkages. Carrying the argument further, Pack and Larry Westphal (1986) and Masahiro Okuno-Fujiwara (1988) commended selective interventions that foster cross-industry externalities as a justification for industrial policy. Noland (2004) applied their argument to Korean experience.

In the post-2000 literature, externalities continue to be stressed as an argument for industrial policy, since a firm seldom keeps all the benefits of its activities nor bears all the costs. R&D and worker training are noteworthy for generating positive externalities. As well, a firm’s successful experience can be reverse engineered by other firms to improve their own technology. These phenomena furnish the foundation for various types of government intervention. Lee Branstetter and Mariko Sakakibara (2002) find that the outcome of Japanese government-sponsored research consortia is positively associated with the level of potential R&D spillover among participating firms.\(^3\)

A new argument for industrial policy is based on the notion of information externality. The logic is that emerging industries make insufficient investment because pioneer firms fear giving free lessons to potential competitors (Hausmann and Rodrik 2003, Lin 2012). Subsidizing pioneers through trade protection and other measures can supposedly offset their inherent disadvantage.

Acquiring productive capability is a time-consuming and costly process, a fact that updates the old infant industry argument and furnishes a new reason for government intervention (Chang 1994, Loasby 1999, Lall 2001, Andreoni 2014). For example, the government of a technology-importing country can force the transfer of core technologies. Industrial policy enthusiasts Karl Aiginger and Dani Rodrik (2020) suggest that policymakers should craft industrial policy not only to mitigate classic market failure but also to address social and environmental challenges. Most recently, in the US-China trade war context, it is argued that the US government should support industries targeted by China to retain US technological leadership and ensure that America does not become subservient to Chinese economic dominance.\(^4\)

For reference, box 1.1 summarizes rationales for industrial policy.

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\(^2\) List (1909). In a recent study Réka Juhász (2018, page 1) finds that “regions in the French Empire which became better protected from trade with the British for exogenous reasons during the Napoleonic Wars (1803–15) increased capacity in mechanized cotton spinning to a larger extent than regions which remained more exposed to trade.”

\(^3\) Strengthening support for government interventions in R&D, Branstetter and Kwon (2004) find that a strong linkage between academic science and industrial technology contributes to research productivity of Japanese firms.

**Box 1.1 Rationales for industrial policy**

- Government should intervene to protect industries that are becoming uncompetitive in the world markets.
- Economic success in Asian countries in the 1970s–80s owes to their industrial policy.
- Government can pick and choose a winner among individual firms and regions in a substantive, efficiency-driven way.
- Government can help US firms adapt to global competition by smoothing the movement of resources out of declining industries and by ensuring the availability of resources to promising sectors.
- Government should defend itself against damaging foreign practices.
- Government should protect infant industries because acquiring productive capability is a time-consuming and costly process for new entrants to the existing market.
- Research and development (R&D) and worker training generate positive externalities. A firm’s successful experience can be reverse engineered by other firms to improve their own technology.
- Potential pioneer firms fear giving free lessons to potential competitors. Subsidizing them through trade protection and other measures can offset their inherent disadvantages such as insufficient investment.

**PRIOR CASE STUDIES**

Since this report is based on case studies, it seems worthwhile to summarize three prior landmark case study volumes: the Rand Corporation’s *Analysis of Federally Funded Demonstration Projects* (Baer, Johnson, and Merrow 1976); Richard R. Nelson’s edited volume *Government and Technical Progress: A Cross-Industry Analysis* (1982); and the collection of studies edited by Linda R. Cohen and Roger G. Noll, *The Technology Pork Barrel* (1991). Though the research approaches adopted in these volumes differ from our approach and are more detailed, the key findings and recommendations are similar.

In 1976 the Rand Corporation published an examination of 24 technology demonstration projects launched in the 1960s or early 1970s and sponsored by federal agencies. The authors were Walter S. Baer, Leland Johnson, and Edward W. Merrow. Projects were evaluated for their commercial success: Was the technology adopted, without further federal support, by private firms or, in some cases, by state and municipal governments?

Ten of the projects succeeded, nine failed, and five had an ambiguous or unknown outcome at the time of publication (table 1.1). The technology worked in some of the failures, but not at commercially attractive terms. In fiscal year 1974, an estimated $625 million was expended on all demonstration projects (including ongoing projects among the 24 examined), a little more than 10 percent of federally sponsored civilian R&D that year, but only 0.2 percent of the FY1974 federal budget ($269 billion). Some 75 percent of the outlays were devoted to energy projects (synthetic fuels, nuclear power).
Table 1.1  
**US industrial policy projects, 1961–75**

<table>
<thead>
<tr>
<th>Project</th>
<th>Period</th>
<th>Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nuclear ship <em>Savannah</em></td>
<td>1962–72</td>
<td>Failure</td>
</tr>
<tr>
<td>Mechanized refuse collection</td>
<td>1969–72</td>
<td>Success</td>
</tr>
<tr>
<td>Computer-assisted electrocardiogram analysis</td>
<td>1969–72</td>
<td>Success</td>
</tr>
<tr>
<td>Teleprocessing of medical claims</td>
<td>1971–74</td>
<td>Failure</td>
</tr>
<tr>
<td>Shipbuilding R&amp;D</td>
<td>1970–??</td>
<td>Unknown</td>
</tr>
<tr>
<td>Fish protein concentrate plant</td>
<td>1966–72</td>
<td>Failure</td>
</tr>
<tr>
<td>Saline water conversion plant</td>
<td>1961–65</td>
<td>Failure</td>
</tr>
<tr>
<td>Dial-A-Ride transportation system</td>
<td>1971–75</td>
<td>Failure</td>
</tr>
<tr>
<td>Yankee Nuclear Power Reactor</td>
<td>1960–??</td>
<td>Success</td>
</tr>
<tr>
<td>Connecticut Yankee Power Reactor</td>
<td>1968–??</td>
<td>Success</td>
</tr>
<tr>
<td>Refuse firing demonstration</td>
<td>1970–??</td>
<td>Success</td>
</tr>
<tr>
<td>Synthetic fuels program</td>
<td>Not specified</td>
<td>Unknown</td>
</tr>
<tr>
<td>Operation Breakthrough (industrialized housing)</td>
<td>1969–??</td>
<td>Failure</td>
</tr>
<tr>
<td>Personal rapid transit system</td>
<td>1972–??</td>
<td>Unknown</td>
</tr>
<tr>
<td>Hydraulic knee prosthetic devices</td>
<td>1959–68</td>
<td>Success</td>
</tr>
<tr>
<td>Rapid excavation and mining (REAM) gun</td>
<td>Not specified</td>
<td>Failure</td>
</tr>
<tr>
<td>Resource recovery from refuse</td>
<td>1971</td>
<td>Failure</td>
</tr>
<tr>
<td>Poultry waste processing</td>
<td>1969–71</td>
<td>Success</td>
</tr>
<tr>
<td>Expressway surveillance and control</td>
<td>1961–??</td>
<td>Success</td>
</tr>
<tr>
<td>Maritime satellite program</td>
<td>1970–??</td>
<td>Unknown</td>
</tr>
<tr>
<td>Refan Jet Engine Program</td>
<td>1972–75</td>
<td>Unknown</td>
</tr>
<tr>
<td>Saline water conversion plant</td>
<td>1962–??</td>
<td>Failure</td>
</tr>
<tr>
<td>Bus-on-Metered Freeway System</td>
<td>1972–75</td>
<td>Success</td>
</tr>
<tr>
<td>Automatic vehicle identification</td>
<td>1971–73</td>
<td>Success</td>
</tr>
</tbody>
</table>

*Source: Baer, Johnson, and Merrow (1976).*
The authors were especially skeptical of large “show” projects and distilled four strategies for successful demonstrations (paraphrased):

- Conduct the demonstration on as small a scale as possible.
- Do not emphasize large projects at the expense of small ones that may deliver incremental improvements.
- Resist political pressure to demonstrate before a technology is well in hand.
- Allow time for slippage, especially for large projects with significant technological uncertainty.

In 1979 Richard R. Nelson, an acknowledged expert on R&D and technological progress, recruited 10 distinguished scholars to examine US public policy and technical progress in seven industries: semiconductors, commercial aircraft, computers, agriculture, pharmaceuticals, residential construction, and motor vehicles. Evaluation of public support focused on events in the 1960s and 1970s. The resulting volume of case studies, some 500 pages, was published in 1982, following a wave of industrial policy initiatives launched by President Jimmy Carter, some of them extended by President Ronald Reagan.

Nelson (1982) summarized findings and recommendations in the concluding chapter. Several of his observations bear repeating, now that President Biden and the Congress are embarking on a fresh wave of industrial policy initiatives:

- The best way for government to stimulate industrial innovation is through R&D support policies. Three types of support are particularly fruitful: (1) public procurement (exemplified by Department of Defense procurement of aircraft); (2) funding of nonproprietary research, allowing the scientific community to guide the allocation of R&D (US agricultural research is the preeminent case); (3) allocation of decision making to potential users to guide the research (Sematech, launched during the Reagan administration, illustrates this approach).
- However, in industries where commercial rivalry is strong (e.g., semiconductors, pharmaceuticals, and motor vehicles) it is difficult for publicly supported but user-guided research to succeed. Proprietary interests of individual companies tend to dominate the research agenda. When rivalry is strong, other modes of R&D support may have greater success.
- To be avoided are R&D projects in which government officials try to identify likely commercial winners. Residential construction R&D and supersonic transport projects pursued during the 1960s and 1970s illustrate this sort of failure.
- The impact of regulation, antitrust, and patents on innovation is complex and varied among different industries (Nelson himself was wary of strong generalizations with respect to these traditional policies). Depending on circumstances, regulation can help or hinder innovation. The same is true for antitrust and patent policies.
Finally, the scholars recruited by Cohen and Noll (1991) generally take a skeptical view of targeted US industrial policies to advance and commercialize technology. They present detailed case studies of six post–Second World War initiatives: American supersonic transport, the applications technology satellite program, the space shuttle, the Clinch River breeder reactor, synthetic fuels from coal, and the photovoltaic commercialization program. Averaging 45 pages per case, the studies take a deep dive into the politics surrounding each, tranches of budget support, technological obstacles, and commercial success or failure. Their conclusions are stark (p. 365): “The history of the federal R&D commercialization programs...is hardly a success story. On the basis of retrospective benefit-cost analysis, only one program—NASA’s activities in developing communications satellites—achieved its objectives and can be regarded as worth the effort.”

While all but one of the programs could be justified by proponents as responses to market failure on the part of commercial firms, the authors identified the following common reasons for government failure:

- Programs were too ambitious, in both their technological aspirations and their scale.
- More upfront research and smaller demonstrations would have been better.
- Demonstrations were often hasty, in politically inspired efforts for a quick “show.”
- Managers were reluctant to cancel programs, even after missed deadlines and mediocre results.
- Budget booms and busts meant too much money at the early stage and too little later on.

Based on their analysis, Cohen and Noll (1991) offered several recommendations, including a restructuring of congressional committees. Their 400-page book concludes with this advice, while acknowledging the difficulty of raising the batting average of commercialization projects (p. 392):

Two firm conclusions can be drawn from the nation’s experiences with commercialization projects: it is desirable to maintain a base program designed to expand commercially relevant technological knowledge, and it is desirable to separate those programs institutionally—in Congress and in the federal bureaucracy—from basic scientific research and from operational responsibilities.

RESEARCH APPROACH

We conclude that it is impossible to refute calls for industrial policy at an abstract level because arguments for intervention build on arguable market failures and, in the instance of Japanese and Chinese success, plausible fears that America will “lose out” to its Asian rivals. The question is whether, in practice, government failures and implementation obstacles severely undermine the case for intervention. Advocates of industrial policy inevitably contend that “this time is different” when confronted with past failures. Nevertheless, an examination of yesteryear cases may, at a minimum, inject a note of caution, and perhaps yield lessons to improve the design of future episodes.
Economists who subscribe to a neoclassical framework may dismiss episodes that seek to create jobs in rising industries, with the argument that balancing unemployment and inflation is the task of the Federal Reserve, not government intervention in specific firms or industries. Economists who are alert to market failures may applaud episodes that seek to save jobs in declining industries, with the argument that smoothing disruption and preserving human capital is a vital task of public policy. Whatever the merits of these views, we assess individual cases from the perspective of proponents who typically count jobs created or saved, ignoring general equilibrium analysis or the value of human capital gained or lost.

Apart from partial equilibrium job counts, proponents typically claim that public support will enable an American industry to develop new technology and become competitive in world markets. Accordingly, we draw on case studies to score several episodes of US industrial policy since 1970, with a view to the hopes and aspirations of proponents. Our choice of episodes is by no means a random sample of state and federal industrial policy. We selected high-profile federal cases plus a very few (out of hundreds) state cases. We divide the episodes into three broad categories reflecting the principal intervention tools (not an economist’s roster of market failures) and evaluate them in the next three chapters:

• cases where trade measures closed the US market or opened foreign markets (chapter 2);
• cases where federal or state subsidies were targeted to specific firms to promote their success (chapter 3); and
• cases where public R&D funds were spent to advance a promising technology (chapter 4).

Chapter 5 concludes by summarizing the outcomes of these varied industrial policies, recounting outright failures, close calls, and clear winners, and then distills lessons for future US industrial policy initiatives. As mentioned, our recommendations echo prescriptions from prior case study volumes.

**SCORING METHODOLOGY**

As Jan Tinbergen (1952) famously observed, successful economic policy needs as many tools as objectives. Yet government often applies a single tool to achieve multiple industrial policy objectives, whether the tool be protection, or regulation, or subsidies. Similarly, industrial policy is often advocated and sold to the public with multiple claims—for example, to launch or rejuvenate an industry, save or create jobs, and/or advance technology. Given this political reality, we examine three features of each episode of industrial policy and for each feature assign a letter grade: A, B, C, or D. Numerical equivalents of these grades, used for the summaries in chapter 5, are A+ = 4.5; A = 4; B = 3; C = 2; D = 1.

Our assessments were based on answers to the following questions, which reflect contemporary objectives:

• Did the industry become competitive in international (or in some cases national) markets? This is the classic test, dating to Adam Smith and John Stuart Mill, of infant industry protection. Success is revealed both by discontinued government assistance and by trade performance. In modern
times, firms may be highly competitive but produce outside the home country. But public officials are more concerned with the location of production than the global strength of particular firms. For that reason, we draw on trade balances as a measure of international competitiveness. We note that US high-tech firms like Apple, Oracle, and Intel often do pathbreaking R&D in the United States, but rely on foreign suppliers, like Foxconn and Taiwan Semiconductor Manufacturing Corporation (TSMC), to manufacture their innovative products for sale in the US market. In such instances, the competitive strength of firms will not be evident in US trade balances. However, US industrial policy is seldom if ever aimed at furthering this division of economic activity. Instead, the common objective of US industrial policy is to promote “good jobs at good wages” in the United States. For that reason, we cite trade balance experience, with an emphasis on exports, to indicate whether the industry became competitive in international markets. In the case of industrial policy at the state level, an analogous test is whether the industry became competitive in the national market without further public support.

- **Were jobs saved in the industry at a reasonable cost to taxpayers or purchasers?** We adopt a generous measure of “reasonable cost”: annual expense to taxpayers or purchasers not exceeding the average wage of employees. This measure of cost is not Arnold Harberger’s (1954) “deadweight loss” of a tariff; rather it is the cost to taxpayers or purchasers. We do not distinguish between the creation of new jobs or the saving of existing jobs in calculating “reasonable cost,” but we note that the economic effects of preventing job displacement may be quite different from enabling job creation. Nevertheless, political proponents seldom make much distinction between jobs created and jobs saved.

- **Was the technological frontier advanced through government assistance?** Like the case study volumes summarized above, our assessments are qualitative judgments, not quantitative measures. We draw on literature surrounding each episode to judge its success in advancing the technological frontier. We do not attempt to put a dollar value on technology generated by government programs. Our assessments primarily apply to industrial policies with large R&D components. Many industrial policies make no attempt to advance the technological frontier but instead are devoted to preserving or extending the application of known technology.

  We do not score the success of an episode in preserving an “essential industry.” Our problem is that defining an “essential industry” is too subjective, too culture bound. For Switzerland, brown cows grazing on Alpine hills are an essential feature of the landscape. For Japan, self-sufficient rice fields are essential, even though rice is easily stockpiled. For Ambassador Robert Lighthizer, steel is an essential industry, no matter the cost. For generations

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5 Commentators may argue that losses of human capital when jobs are disrupted (“hysteresis” effects) are far more severe than gains in human capital when jobs are created. Hence, “saving” 1,000 existing jobs is more important than “creating” 1,000 new jobs. Perhaps true, but, as noted, this study does not attempt to measure human capital lost or gained as a result of industrial policy.
of Congressmen, the merchant marine has been an essential industry, despite Pentagon skepticism and the opposition of no less a naval hero than Senator John McCain. “Essential industries” are often conflated with national security, but seldom do advocates entrust the Pentagon with the budget to decide which industries are truly essential. Given such definitional hazards, we conclude that preserving an “essential industry” cannot be scored as success or failure. The very label bars inquiry: once an activity is claimed to be essential, the advocate has already decided that evidence on cost or performance is irrelevant.

More must be said about the jobs dimension of industrial policy. President Biden declared, in his maiden address to Congress on April 28, 2021, that jobs were the heart of his infrastructure proposal, then labeled the American Jobs Plan, and his Buy American mandates. Most economists contend that macroeconomic policy, not industrial policy, is the right tool for creating jobs in a depressed economy. Moreover, they point out that jobs with political salience in the United States are usually in production and construction, jobs that seldom require a college education. Unemployment, even during the COVID-19 pandemic, was low for college-educated workers, particularly those with degrees in science, technology, engineering, or mathematics (STEM). Yet many episodes of industrial policy essentially provide alternative employment for STEM workers, not for workers lacking a college degree. Finally, economists are quick to note that industrial policy may save or create jobs in a particular firm or industry but at the expense of (1) employment in downstream firms that are forced to buy more costly inputs, (2) successful firms that might have employed the workers released by failing firms, or (3) neighboring states that might otherwise have attracted a subsidized firm.

In declining industries, a better criterion than “jobs saved” for evaluating industrial policy would be “jobs restructured.” Decades ago, just such an approach was proposed for industries troubled by import competition (Hufbauer and Rosen 1986), and many economists since have advocated more robust US measures for dislocated workers. While justified, restructuring is not a goal in the contemporary renaissance of industrial policy, and we do not include a restructuring metric among our criteria.

We take note of all these points and objections and state them here once and for all, rather than repeating them as we review each episode. Out of sympathy to current proponents of industrial policy, led by President Biden, our job counts refer only to jobs saved or created in the targeted firm or industry, not jobs lost or gained elsewhere in the economy, and we do not distinguish between skill levels. This is the metric of the advocates’ political case. Our study attempts to address that case, not dismiss it by the economist’s conception of labor market dynamics. In this important dimension, our scoring of episodes is quite generous to proponents of industrial policy.

Finally, we recognize that industrial policy has the potential to improve or worsen “welfare” as defined by economists (usually measured by an increase or decrease in GDP). Improvements are particularly likely when government intervention targets a cost or benefit that is external to private firms (e.g., carbon

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The transcript of the speech is available at [www.whitehouse.gov/briefing-room/speeches-remarks/2021/04/29/remarks-by-president-biden-in-address-to-a-joint-session-of-congress/].
emissions or internet standards). Industrial policy can worsen welfare through measures that cost more than their benefits—white elephants abound in the episodes that follow. Seldom does government assess, in a serious quantitative manner, whether an intervention will improve or worsen welfare. Nor do we attempt to measure welfare gained or lost in each episode. Instead, the three criteria we have enumerated focus on features commonly claimed by supporters of industrial policy.

**COMPARATIVE SIZE OF US INDUSTRIAL POLICY**

In the United States, government-driven industrial policy claims a relatively small share of federal and state budgets. Table 1.2 summarizes the approximate annual cost of selected federal industrial policies discussed in this report as well as the prospective cost of initiatives on President Biden’s watch. Annual consumer costs of seven trade measures examined in this study reach $29.5 billion, a figure that would be substantially higher if unidentified trade measures (e.g., concerning sugar, the merchant marine, etc.) were recorded. Annual average funding for R&D programs under DARPA is about $3.2 billion, and for solar and wind research about $1.4 billion. The prorated annual cost for semiconductor manufacturing and industrial R&D contemplated under the American Innovation and Competition Act could reach $66 billion over the next few years. All told, the total annual cost of federal industrial policies might reach $100 billion, accounting for 2.4 percent of the annual federal budget. With Biden's initiatives, this prospective total easily exceeds annual federal industrial policy expenditures during the period covered by this report, 1970 to 2020.

State industrial policies must be considered as well. States offer numerous incentives, and this report covers only four episodes. State-driven industrial policy includes cash grants, corporate income tax credits, sales tax exemptions or refunds, property tax abatements, low-cost loans or loan guarantees, and free services like worker training. To estimate a comprehensive figure, we rely on a 2012 *New York Times* summary that suggests an annual total of nearly $25 billion. Another source, recorded in a note to table 1.2, suggests a much smaller annual total of only $8 billion. In any event, the larger *New York Times* figure represents just 1 percent of the annual average budget outlays of all 50 states and the District of Columbia.

We conclude that the annual magnitude of US federal and state industrial policies is modest compared to past experience in East Asia or current experience in China, both discussed in the concluding chapter.
Table 1.2
Approximate annual cost for selected federal and state industrial policies, compared with budget outlays (billions of dollars)

<table>
<thead>
<tr>
<th>Policy</th>
<th>Federal</th>
<th>State</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Federal industrial policies</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Annual consumer costs for the identified trade measures in this report*</td>
<td>29.5</td>
<td></td>
</tr>
<tr>
<td>Annual average DARPA budget (2015–2019) in 2020 dollars</td>
<td>3.2</td>
<td></td>
</tr>
<tr>
<td>Annual average DOE solar and wind program budget (2015–2019) in 2020 dollars</td>
<td>1.4</td>
<td></td>
</tr>
<tr>
<td>American Innovation and Competition Actb</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Semiconductor manufacturing (prorated over 2 years)</td>
<td>26.0</td>
<td></td>
</tr>
<tr>
<td>Other industrial R&amp;D (prorated over 4 years)</td>
<td>40.0</td>
<td></td>
</tr>
<tr>
<td><strong>State industrial policiesc</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Corporate tax exemptions</td>
<td>15.9</td>
<td></td>
</tr>
<tr>
<td>Property tax abatements</td>
<td>6.8</td>
<td></td>
</tr>
<tr>
<td>Cash grants and loans</td>
<td>1.8</td>
<td></td>
</tr>
<tr>
<td>Free services</td>
<td>0.2</td>
<td></td>
</tr>
<tr>
<td><strong>Totals</strong></td>
<td>100.1</td>
<td>24.7</td>
</tr>
<tr>
<td>Annual average budgets (2015–2019) in 2020 dollars</td>
<td>4,225.3</td>
<td>2,453.8</td>
</tr>
<tr>
<td>Total industrial policy costs as percent of budget totals</td>
<td>2.4</td>
<td>1.0</td>
</tr>
</tbody>
</table>

a. In addition to the cases in this study, Hufbauer and Elliott (1994) report the cost of other trade measures on ball bearings, benzenoid chemicals, canned tuna, ceramic articles, costume jewelry, frozen orange juice, glass and glassware, luggage, polyethylene resin, rubber footwear, softwood lumber, women’s footwear and handbags, dairy products, peanuts, sugar, machine tools, and maritime services. Many of these measures are still in effect.
b. Total funding is projected to be about $252 billion over 2 to 4 years.

Note: Based on data provided by Good Jobs First’s Subsidy Tracker team, cumulative state subsidies between 2001 and 2021 were about $162 billion (about $8 billion per year), www.goodjobsfirst.org/subsidy-tracker (accessed on June 16, 2021).

REFERENCES


2 Industrial Policy
Through Trade Measures

INTRODUCTION
The use of trade measures—usually protection against imports, but occasionally assistance for exports—is a classic form of industrial policy. Indeed, the “infant industry” argument was recognized by no less authorities than Adam Smith (1776) and John Stuart Mill (1885) as a valid case for protection, provided that the protected industry can eventually compete in world markets without government assistance.

In US practice, however, few trade measures can plausibly be justified on infant industry grounds. Marcus Noland (1993) looked at the strategic trade argument with respect to competition from Japan and found that the targeting was not successful in general. Yet numerous episodes can be found in the past 50 years of US industrial policy implemented through trade measures. Whether or not they pass the Smith/Mill test for the proper application of infant industry protection, trade measures appeal to both Democratic and Republican presidents for four reasons:

• The cost is “off budget”—politicians claim that tariffs act as taxes paid by foreign sellers, even though research (e.g., Feenstra 1984 and Bown 2021) shows that tariffs are almost always passed on in higher prices to domestic buyers.
• Protection is said to “save” domestic jobs, but jobs lost in downstream industries that must pay for higher-priced inputs are ignored.
• Foreign exports are often characterized as unfair—subsidized, dumped, or based on stolen technology—owing to industrial policy abroad. And US exports may face market access barriers, unfairly constraining US sales.
• Finally, broad national security arguments are invoked to preserve the domestic industry.

In this chapter, we examine five high-profile episodes to illustrate the use of trade measures to carry out industrial policy. The episodes concern steel, textiles and apparel, automobiles, semiconductors, and solar panels.

STEEL
Large segments of the US steel industry have been shielded from import competition since 1969. This is not an industrial policy to accelerate growth or correct for externalities. The objective is to preserve jobs and cushion decline.

At the outset of what has become a half-century of industrial policy implemented through trade protection, Europe and Japan were the main foreign competitors. Later, South Korea, Turkey, Mexico, Brazil, and Argentina became important exporters. Most recently, Chinese exports have disrupted global steel markets, prompting a fresh round of protection.
Since nearly all foreign suppliers are supported by a mix of public subsidies, bailouts, and import barriers, the global steel market can be characterized as a gigantic clash of national industrial policies. Proponents of steel protection might view this clash as exemplifying market failure on a world scale. In May 2021 Senators Rob Portman (R-OH) and Sherrod Brown (D-OH) began seeking to “update” US trade remedy laws in a manner that, among other features, would make continued protection of the US steel industry even easier.7

Table 2.1 summarizes various types of US steel protection. Countervailing duty (CVD) and antidumping duty (AD) orders are designed to offset foreign subsidies and below-cost exports to the US market. Broadly speaking, these forms of protection (penalty duties) are designed to counter “unfair” industrial policies abroad. Intermittent special protection regimes—“voluntary” import restraints (VRAs), “voluntary” export restraints (VERs), trigger price mechanisms, safeguard duties, or national security tariffs—are designed to fill gaps remaining after the application of CVD and AD penalty tariffs.

From 90 million metric tons in 1990, US domestic production of steel peaked at 102 million tons in 2000, and has since fallen to 88 million metric tons in 2019. US steel exports increased from 3.9 million metric tons in 1990 to 12.5 million metric tons in 2012 but declined to 6.7 million metric tons in 2019. US steel imports rose from 15.6 million metric tons in 1990 to 40.2 million metric tons in 2014, and then fell to 25.3 million metric tons in 2019 as protective barriers rose (see figure 2.1).

It’s worth noting that the US export unit value, in nominal dollars, increased from $1,351 per ton in 2012 to $1,473 per ton in 2019, while the import unit value declined from $1,121 per ton to $932 per ton in the same period. The price gap between US exported and imported steel reflects higher-quality exports. In other words, US mills possess a niche advantage in making products requiring advanced technology. Advanced steel grades, for example, are used as lightweight automotive materials without compromising safety.8 Other technological advances improve the environment; for example, Organic Rankine Cycle turbines reduce carbon emissions and need less water for the cooling system.9

But after 50 years it’s impossible to justify industrial policy in the steel industry on infant industry grounds. Indeed, US trade protection is now justified as an answer to “unfair” foreign practices that damage an “essential” industry. Despite the minimill revolution and other technological advances that translate into more or higher-quality tons per labor-year, US steel firms feel no better able to meet foreign competition in 2020 than they did in 1970. Based on Peterson Institute analysis of multiple protection episodes, the resulting average markup

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in domestic steel prices is about 4.8 percent.\textsuperscript{10} Applying that figure to 30 years of cumulative domestic steel production, amounting to 2.68 billion tons (1990–2019) evaluated at the 2019 import price per ton of $932, trade protection has cost the US economy $120 billion.\textsuperscript{11} This figure exceeds the current enterprise value of all publicly traded steel firms, a figure under $100 billion.\textsuperscript{12} Though iconic, the steel industry is small relative to US GDP, and the cost works out to about $4 billion a year ($120 billion divided by 30 years).

Given this arithmetic, the case for continued protection of the domestic steel industry has shifted to arguments about an “essential industry,” with national security overtones, and the middle-class jobs argument. These arguments attract strong bipartisan support, judging from declarations by both President Donald Trump and President Joe Biden. Advocates of an essential industry argument tend to see an “all-or-nothing” world. Without protection, they argue, the US steel industry will disappear. However, the experience of other countries indicates that domestic steel industries can survive without permanent high protection; Canada, Australia, Sweden, and South Korea are examples. Moreover, it should be noted that, quite apart from trade protection, Buy American laws ensure that domestic mills supply specialized steel for military use and steel used in federal infrastructure projects, at elevated cost to taxpayers.

Finally, there is the middle-class jobs argument. Figure 2.2 records steel industry employment and tons per labor-year. Employment in iron and steel mills and ferroalloy production fell from 186,800 employees in 1990 to 87,300 employees in 2019 while steel productivity grew from 480 metric tons per employee in 1990 to 1,006 metric tons per employee in 2019. However, as the chart shows, productivity has not increased since 2002, measured by tons per labor-year. One study found that minimills, and their competitive impact on blast furnace mills, were mainly responsible for massive productivity growth between 1963 and 2002 (Collard-Wexler and De Loecker 2015). Since then, high-quality steels are the main contributor to rising productivity.

\begin{footnotes}
\item[10] Tariffs and quotas imposed on steel imports between 1982 and 1992 contributed to about 12 percent of domestic price increase (Hufbauer and Elliott 1994), and antidumping and countervailing duties imposed on steel products in 1993–98 caused about 4 percent of domestic price increase (Hufbauer and Elliott 1994). During the Bush administration, steel safeguard duties increased the price 3.3 percent (Hufbauer and Goodrich 2003). And Trump’s Section 232 tariffs had an impact on raising the domestic steel price by 9 percent between 2017 and October 2018. Using these numbers between 1990 and 2018, the year weighted average markup for domestic steel price is about 4.8 percent.
\item[11] Steel price from US Commerce Department’s Steel Import Monitor (accessed on June 23, 2021).
\item[12] As of November 25, 2020, market capitalization of steel companies is as follows: $29 billion for Arcelor Mittal, $3 billion for AK Steel (acquired by Cleveland-Cliff in March 2020), $19 billion for Nucor, $7 billion for US Steel, $9 billion for Steel Dynamics, and $3 billion for Commercial Metals. Data are from the Fidelity website and Google for AK Steel.
\end{footnotes}
Table 2.1
Summary of US steel trade protection measures, 1968–2020

<table>
<thead>
<tr>
<th>Protection</th>
<th>Definition</th>
<th>Use</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Type 1</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Antidumping duty (AD)</td>
<td>Dumping occurs when a foreign manufacturer sells its product at a price below market value. AD is applied when dumped imports have caused material injury to a US industry. The duties are assessed as a percentage of the value of the imports and are equivalent to the dumping margins.</td>
<td>Total 206 AD investigations on steel imports from 38 countries have been launched since 1968.</td>
</tr>
<tr>
<td>Countervailing duty (CVD)</td>
<td>A CVD is designed to provide relief to domestic industries that have been materially injured by subsidized imports. The duties are assessed as a percentage of the value of the imports and are equivalent to the subsidy margins.</td>
<td>Total 66 CVD investigations on steel imports from 11 countries have been launched since 1968.</td>
</tr>
<tr>
<td><strong>Type 2</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Voluntary import and export restraints (VERs)</td>
<td>A VER is a restriction set by a government on the quantity of goods that can be exported during a specified period of time. Often the word voluntary is placed in quotes because these restraints are typically implemented at the insistence of the importing nations. VERs arise when import-competing industries seek protection from a surge of imports from particular exporting countries. VERs are then offered by the exporter to appease the importing country and to avoid the effects of possible trade restraints imposed by the importer.</td>
<td>1968 Steel Voluntary Restraint Agreement (VRA) was signed to restrict US steel imports from Japan and the European Coal and Steel Community (ECSC) by allocating import quota. Japan and the ECSC were each given 41 percent of the total US steel imports, 5.75 million net tons. 1972 Steel VRA was signed to grant 6.5 million tons and 8 million tons for Japan and the ECSC, respectively. The Reagan administration in 1984 negotiated VRAs with 29 nations, restricting steel imports to 20 percent of the US market until September 1989. The objective announced was market-determined import penetration of approximately 18.5 percent.</td>
</tr>
<tr>
<td>Trigger price mechanism (TPM)</td>
<td>The TPM was devised to detect imports of steel at unfairly low prices and trigger administrative relief provided by law. The TPM established reference prices for steel imports. Imports at prices below the reference price would trigger an investigation of whether imports were being dumped or subsidized. The ostensible purpose of the TPM was to provide data to detect more rapidly and investigate more quickly dumping of foreign steel.</td>
<td>The TPM covered 32 steel products. The Commerce Department established base prices for most steel products, using cost of the product in Japan, and then determined the trigger price by adding shipping costs to the base price amounts. On January 3, 1978, the Treasury Department announced the first TPM for steel products; it was suspended on March 21, 1980.</td>
</tr>
<tr>
<td>Protection</td>
<td>Definition</td>
<td>Use</td>
</tr>
<tr>
<td>--------------------</td>
<td>---------------------------------------------------------------------------</td>
<td>----------------------------------------------------------------------</td>
</tr>
<tr>
<td>Safeguard duty</td>
<td>A safeguard investigation requires no demonstration that steel imports</td>
<td>In March 2002 President Bush chose to impose tariffs on 14 of the 16</td>
</tr>
<tr>
<td></td>
<td>are sold unfairly. In December 2001 the commissioners gave their remedy</td>
<td>products found by the International Trade Commission to be injuring</td>
</tr>
<tr>
<td></td>
<td>recommendations to President George W. Bush—remedies that took the form</td>
<td>the domestic steel industry. He imposed 15-30% tariffs on steel</td>
</tr>
<tr>
<td></td>
<td>of tariffs, quotas, or tariff-rate quotas (TRQs) on the injurious imports.</td>
<td>products and also adopted a TRQ: all imports in excess of 6 million</td>
</tr>
</tbody>
</table>
<pre><code>                                                                                                                             | short tons were subject to a tariff of 30 percent; slab imports up   |
                                                                                                                             | to 6 million short tons faced no additional duty. The safeguard      |
                                                                                                                             | remedies were abolished after March 2005.                           |
</code></pre>
<p>| National security  | Section 232 of the Trade Expansion Act of 1962 under certain circumstances | The Trump administration invoked Section 232 on the national security |
| tariff (Section 232)| allows the president to impose tariffs based on a recommendation from the US| ground that domestic steelmakers must be shielded today in case a   |
|                    | Secretary of Commerce if “an article is being imported into the United    | future war deprives the Pentagon of essential steel. On March 23,    |
|                    | States in such quantities or under such circumstances as to threaten or    | 2018, the Trump administration imposed a 25 percent duty on most      |
|                    | impair the national security.”                                           | steel imports. Quotas were soon agreed with Argentina, Brazil, and   |
|                    |                                                                          | South Korea. As of early 2020 Australia, Mexico, and Canada were     |
|                    |                                                                          | exempted from the tariffs.                                           |</p>


Figure 2.1
US steel production and trade (million metric tons), 1990–2019

Sources: USGS Iron and Steel Statistics and Information and US Commerce Department Global Steel Trade Monitor (various reports).
Remorse over manufacturing jobs lost is a powerful force in American politics. Yet, whatever a half-century of trade protection did for maintaining steel production, it has not preserved steel employment. Moreover, the cost paid by steel users per job “saved” in the steel industry has been stratospheric. US consumers and businesses are currently paying more than $900,000 a year for every job saved by Trump’s steel tariffs, extended by Biden.\textsuperscript{13} In turn, this high cost has curtailed output and employment in downstream industries. According to one analysis, President Trump’s Section 232 tariffs might have slashed employment by 433,000 jobs in the rest of the economy while increasing employment in the steel industry by just 26,000 jobs over three years (Francois, Baughman, and Anthony 2018). Nevertheless, since benefits of protection are concentrated while costs are widely distributed, political arithmetic strongly supported the Section 232 tariffs.

Alternative policies might have averted the long-term unemployment, urban decay, and “deaths of despair” that accompanied the loss of steel industry jobs. Clearly the American political system did not deliver those alternatives, preferring under Trump’s escalated steel tariffs to pay $11.5 billion a year in higher steel costs for the false hope of a revival due to industrial policy.\textsuperscript{14}

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\textsuperscript{13} Heather Long, “Trump’s steel tariffs cost U.S. consumers $900,000 for every job created, experts say,” \textit{Washington Post}, May 7, 2019. Total US consumption of steel products in 2018 was 109 million tons, and the average price of steel imports was $960 per ton. By multiplying 109 million by $960 per ton, the total value of steel consumption was about $115 billion. A rough estimate of the additional cost attributable to the tariffs is 10 percent of $115 billion. If we divide the additional cost ($11.5 billion) by 12,737 steel jobs created/saved, we get the consumer cost per steel job, which is about $903,698. The job number was from the American Alliance for Manufacturing.

By way of comparison, we note that, although few similarities exist between the production conditions of sugar and steel, what they have in common is very long-term protection. In 1922 the Fordney-McCumber Tariff launched a century of high protection for sugar plantations, and steel protection has now reached the half-century mark. Despite economic failures, protection in both cases has achieved an equilibrium in the American political system: evident costs are approximately balanced by political payoffs.  

Summary Evaluation and Brief Explanations

• Has the US steel industry become internationally competitive? Failed outcome = D

The industry clings to protection in 2020 as strongly as it did in 1970. During the Trump administration (2017–21), national security tariffs of 25 percent were added to the existing armory of barriers (initially across the board, later subject to exceptions). Exports of steel, concentrated in high-value products, amounted to 8 percent of domestic production in 2019, about the same percentage recorded in 1970.

• Did protection save jobs at a reasonable cost? Failed outcome = D

Per job saved in the steel industry, the cost to steel users was near the top of US protection episodes. Trump’s national security tariffs cost steel users about $900,000 annually per steel industry job saved, a figure many times the industry’s average annual wage of $59,000 in 2019.

• Did protection advance the technological frontier of steel production? Failed outcome = D

The biggest technological advance in the past half-century—but not as a consequence of protection—was the rise of minimills, which make an ever larger range of steel items from scrap. The shift to minimill production continues to grow owing to the demand for high-quality steel. The leading minimill producer, Nucor, advocated free trade until former CEO Ken Iverson died in 2002. The industry has made other innovations, but none as spectacular.

TEXTILES AND APPAREL

Restrictions on textile and apparel trade have been a mainstay of industrial policy through trade protection in nearly all advanced economies since the 1930s. The objective was to slow, or even halt, the rise of imports as comparative advantage shifted to developing economies. The overriding goal was to cushion

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15 The steel industry donated $5 million to political causes in 2019–2020, and agribusiness donated $120 billion. By comparison, the finance, insurance, and real estate sector donated about $1.5 billion in 2019–20, and the health sector and communication/electronics sector contributed about $482 million and $457 million, respectively. For details, see www.opensecrets.org/elections-overview/sectors (accessed on October 23, 2020).


employment losses in advanced nations. Few observers today regard textiles and apparel as a strategic industry critical to technological leadership or military power. As with steel, industrial policy for this sector has other objectives. Since the Uruguay Round of Multilateral Trade Negotiations (1986–93), no American president has been willing to further expose the US textile and apparel industry to global market forces, but some liberalization has been allowed in the context of regional trade agreements.

Prior to the Second World War, the United States and other countries sought to limit textile imports from Japan. In 1957, at US insistence, Japan agreed to a five-year “voluntary” restraint program. Western Europe imposed similar quantitative restrictions. These bilateral arrangements paved the way, in 1961 under the General Agreement on Tariffs and Trade, for the Short-Term Arrangement Regarding International Trade in Cotton Textiles (STA). The STA, covering 64 categories of cotton textiles, enabled importing countries to impose unilateral quantitative restraints. It was followed in 1962 by the Long-Term Arrangement (LTA) covering all textiles containing more than 50 percent cotton by weight or value. US textile and apparel tariffs were exempted from cuts during the Kennedy Round of Multilateral Trade Negotiations (1964–67).

The LTA was succeeded, in 1974, by the comprehensive First Multi-Fiber Arrangement (MFA I), which covered virtually all textile and apparel trade until 1977. It was succeeded by MFA II (1978–81), MFA III (1982–86), and MFA IV (1986–93). The successive MFAs authorized detailed product and country export quotas, allowed limited growth, and gave importing countries wide discretion. The overriding goal remained: keep job losses below politically tolerable levels. As a side effect, the MFA system created a rent seekers’ paradise and a lawyer and lobbyist bonanza in both importing and exporting countries.

A key political bargain underlying the Uruguay Round was termination of the MFA system by advanced economies in exchange for acceptance of intellectual property protection (TRIPS) and a framework agreement on services trade (GATS) by developing economies. At the end of the Uruguay Round of negotiation, members agreed to phase out MFA quotas by January 1, 2005.

Not anticipated by developing economies at the conclusion of the Uruguay Round was that China would be a major beneficiary of quota-free trade in textiles and apparel. With its comparative advantage in low cost of labor and superior logistics, China increased textile and apparel exports from 11 percent and 12 percent of world textile and apparel exports respectively in 1995, to 48 percent and 34 percent respectively in 2018. By value, textile and apparel exports from China to the world grew from $3.5 billion in 1989 to $47.4 billion in 2018.

At the conclusion of the Uruguay Round, the United States retained its relatively high tariff profile on textile and apparel imports, summarized in table 2.2. But tariffs were reduced in bilateral and regional trade agreements, notably NAFTA, with the requirement that apparel exported by a partner country to the United States should be made with yarn or fabric originating in the partner country or the United States, the so-called yarn forward rule. As a result of this bargain, simple average tariffs on US imports from the world declined on every product category between 1995 and 2019.
Table 2.2
Simple and trade-weighted average US tariffs (percent) on textiles and apparel, 1995 and 2019

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>50</td>
<td>Silk</td>
<td>3.5</td>
<td>4.2</td>
<td>0.7</td>
<td>0.4</td>
</tr>
<tr>
<td>51</td>
<td>Wool</td>
<td>8.4</td>
<td>10.1</td>
<td>6.0</td>
<td>10.1</td>
</tr>
<tr>
<td>52</td>
<td>Cotton</td>
<td>10.0</td>
<td>9.2</td>
<td>8.4</td>
<td>7.8</td>
</tr>
<tr>
<td>53</td>
<td>Other vegetable textile fibers</td>
<td>2.4</td>
<td>4.1</td>
<td>0.9</td>
<td>0.9</td>
</tr>
<tr>
<td>54</td>
<td>Man-made filament</td>
<td>13.9</td>
<td>13.1</td>
<td>10.1</td>
<td>7.8</td>
</tr>
<tr>
<td>55</td>
<td>Man-made staple fibers</td>
<td>14.5</td>
<td>11.1</td>
<td>10.5</td>
<td>6.4</td>
</tr>
<tr>
<td>56</td>
<td>Wadding, felt and nonwovens</td>
<td>9.1</td>
<td>7.9</td>
<td>4.4</td>
<td>2.0</td>
</tr>
<tr>
<td>57</td>
<td>Carpets and other textile floor coverings</td>
<td>5.9</td>
<td>6.0</td>
<td>2.8</td>
<td>2.4</td>
</tr>
<tr>
<td>58</td>
<td>Special woven fabrics</td>
<td>11.9</td>
<td>9.0</td>
<td>8.5</td>
<td>6.9</td>
</tr>
<tr>
<td>59</td>
<td>Impregnated, coated or laminated textile</td>
<td>6.2</td>
<td>6.4</td>
<td>3.2</td>
<td>3.9</td>
</tr>
<tr>
<td>60</td>
<td>Knitted or crocheted fabrics</td>
<td>13.8</td>
<td>13.4</td>
<td>10.3</td>
<td>11.1</td>
</tr>
<tr>
<td>61</td>
<td>Articles of apparel and clothing, knitted</td>
<td>15.5</td>
<td>15.8</td>
<td>12.7</td>
<td>14.7</td>
</tr>
<tr>
<td>62</td>
<td>Articles of apparel and clothing, not knitted</td>
<td>12.3</td>
<td>12.5</td>
<td>10.7</td>
<td>11.2</td>
</tr>
<tr>
<td>63</td>
<td>Other made-up textile articles</td>
<td>9.0</td>
<td>9.2</td>
<td>6.9</td>
<td>7.4</td>
</tr>
</tbody>
</table>


When MFA IV came to an end in 1993, US textile and apparel imports surged (figure 2.3). US apparel imports nearly quadrupled from $22 billion in 1989 to $86 billion in 2018; textile imports increased at a slower pace but nonetheless grew substantially from $8 billion in 1989 to $50 billion in 2019. In contrast, US apparel exports did not grow much during this period, though US textile exports did increase. US free trade agreement (FTA) partners have become the main US export destinations, accounting for about 70 percent of US textile and apparel exports in 2019 (figure 2.4). But their share in US textile and apparel imports shrank from around 20 percent and 25 percent respectively in 1989, to 14 percent and 18 percent respectively in 2019, reflecting China’s entry to global trade.

While US employment and production in the textile and apparel industries have both declined since 1989, the textile industry is performing somewhat better in terms of production (figures 2.5 and 2.6). Employment in 2020, in both textiles and apparel, was just a fraction of its MFA IV level in 1995, reflecting adjustment
to market realities: increased productivity and competition from abroad. To a significant but lesser extent, production in both sectors declined, but not so much in the textile industry.

Figure 2.3
US global trade in textiles and apparel, 1989–2019


Figure 2.4
US textile and apparel trade with FTA partners, 1989–2019


FTA = free trade agreement
Figure 2.5
**US employment in textiles and apparel, 1990–2020**

thousands of employees

Note: All employees, monthly, seasonally adjusted.

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Figure 2.6
**US gross output in textiles and apparel, 1987–2020**

billions of current US dollars

The United States exports significantly higher value textiles than it imports. For fabrics measured in square meters, the average import unit value in 2019 was $5.80 per square meter, while the average export unit value was $10.50 per square meter. The difference reflects the high-tech orientation of the US textile industry, which produces durable fabrics for military and medical applications, car seats, household and office carpets, and much else. By contrast, imported textiles lean toward cotton fabrics for apparel, towels, bedding, and other general use purposes.

During the MFA IV period (1986–93), average tariff and nontariff barriers on textile imports were about 23 percent ad valorem (Hufbauer and Elliott 1994). Textile employment was about 594,000 workers; without protection, approximately 16,200 jobs would have been lost. The consumer cost of textile protection was about $3.3 billion, or about $200,000 per job “saved.” At the time average annual US wages in textile production were about $17,000.

Also during the MFA IV period, average tariff and nontariff barriers on apparel imports were about 48 percent ad valorem (Hufbauer and Elliott 1994). Apparel employment was about 871,000 workers, and without protection approximately 152,600 jobs would have been lost. The consumer cost of apparel protection at that time was about $21.2 billion, or about $114,000 per job “saved.” Average annual US wages in apparel production were about $12,400.

In 2019 nontariff barriers had practically disappeared, and weighted average tariffs were lower than during the mid-1990s, mainly owing to free trade agreements with Mexico and Central and South America. The weighted average tariff for textile imports was 8.1 percent and for apparel imports 10.7 percent—high compared to the US average MFN tariff of 2.3 percent, but lower than the mid-1990 levels.

Consequently, the current consumer cost of protection is much lower for apparel, $10.2 billion annually, and fractionally lower for textiles, $3.2 billion annually (for calculations on textiles, see appendix A). These are nominal dollar figures, so in real terms the drop is greater. Nevertheless, relative to jobs “saved,” consumer costs have gotten even higher. Protection of apparel production now “saves” about 6,300 jobs, implying a cost of $1.6 million per job, while the average wage is $33,100. Protection of textile production saves 2,200 jobs, implying a cost of $1.4 million per job, while the average wage is $33,300.

Summary Evaluation and Brief Explanations

- **Has the textile and apparel industry become internationally competitive?**
  
  Failed outcome = D
  
  US MFN tariffs on textile and apparel imports remain higher than other US tariffs on manufactured imports. Compared to the year 2007, productivity in the textile and apparel industries has not substantially improved since the Global Financial Crisis.

- **Did protection save jobs at a reasonable cost?** Failed outcome = D
  
  Per job saved in the textile and apparel industry, the cost in 2019 was extreme. US tariffs on textile and apparel products in 2019 cost consumers about $1.4 million and $1.6 million per job, respectively.

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18 Textile import and export prices were averaged of all import and export prices of textile measured by square meters. Data were collected from US Census Bureau.
Did protection advance the technological frontier of textile and apparel production? Intermediate outcome = C

Individual textile firms invested in R&D to produce high-tech and nonwoven fabrics with applications in the military, medical, infrastructure, landscaping, household, and automotive markets. For example, Milliken’s ResQ™ fabric, used by the military and fire and rescue services, and Glen Raven’s water filtration fabric for removing salt from seawater are the outcome of domestic R&D. To some extent, textile protection provided financial resources for these and other innovations.

AUTOMOBILES

Led by Henry Ford, Walter Chrysler, John Dodge, and other visionaries, the United States pioneered mass production of autos in the 1920s. After the Second World War, the Detroit Three—Ford, Chrysler, and General Motors—dominated global automotive production. But by the late 1970s, Japan was a formidable competitor, with engineering innovations and new production techniques. Less competitive to Japan, Germany, Sweden, and the United Kingdom maintained their share in the US automobile market.

Prior to Japan’s arrival on the automotive scene, the US government played a limited role in auto affairs (for details, see Lawrence White’s chapter in Nelson 1982). Its most important impacts were through legislation designed to control emissions: the Motor Vehicle Air Pollution Act of 1965, the Clean Air Act of 1970, and the Energy Policy and Conservation Act of 1975. Over time these laws led to progressively more demanding emissions controls and mileage performance.

Various initiatives launched by successive presidential administrations met with limited success. The Carter administration in 1978 tried to establish the joint Cooperative Automotive Research Program (CARP), between the Detroit Three and the federal government, to enhance mileage per gallon. The target federal contribution was just $50 million per year (never reached), and CARP was abandoned by the Reagan administration to the quiet applause of the Detroit Three.

In 1993 the Clinton administration launched the Partnership for a New Generation of Vehicles (PNGV), a research program funded by several federal agencies and the Big Three automakers, to develop fuel-efficient vehicles by 2003. Total federal funding reached about $250 million per year. The PNGV program improved aluminum sheet and carbon-fiber composites, reducing production costs and recycling materials. However, questions were raised about mass production, the environmental impact of diesel engines in hybrid designs, and high prices.19

US industrial policy in the auto sector was truly launched in 1980 with a safeguard petition filed by the United Auto Workers (UAW) to the International Trade Commission (ITC). Ford Motor Company later joined the petition, asking the federal government to limit total US auto imports to 1.7 million passenger vehicles and 260,000 light trucks.20

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At the time, and still today, the US tariff rate on imported autos was 2.5 percent, and similarly low rates applied to imported parts. However, as a relic of the “Chicken War” dispute with Europe in the 1960s, the US tariff on imported heavy trucks and pickup trucks was 25 percent, effectively barring imports of those vehicles. Consequently, the industrial policy battle focused on autos and parts (later including minivans and sport utility vehicles), which were never subject to the 25 percent Chicken War tariff.

Despite support from President Jimmy Carter and influential senators and congressmen, in November 1980 the ITC rejected the UAW/Ford plea for relief, finding ample domestic causes for the industry’s woes. Carter then awarded Trade Adjustment Assistance (TAA) to displaced workers (organized labor derided TAA as “burial insurance”) and in 1981 directed the USTR to negotiate the first of several “voluntary” restraint agreements with Japan. The VRAs were renewed each year until 1985, when they were discontinued by President Ronald Reagan. Japan nevertheless continued to exercise “self-restraint” and limited exports until the 1990s.

Steven Berry, James Levinsohn, and Ariel Pakes (1999) suggest that voluntary restraints increased the profits of US producers because they sold more cars. US producers did not significantly raise their prices because consumers who switched from Japanese to domestic cars were price sensitive. However, Japanese firms raised their prices during the restraint period, on average by more than $1,000 per car, resulting in additional costs to the US public of about $2.8 billion.

By the 1990s Japanese “transplant” firms were producing most of the foreign autos purchased by Americans. Very early, Toyota, Nissan, and Honda had seen the writing on the wall and realized that trade restrictions would endure, so they established auto production facilities in the United States. Toyota and Honda debuted as auto manufacturers on American soil in 1982 and Nissan did so a year later. The early stage of US industrial policy for the auto industry accelerated the migration of Japanese and European auto assembly firms, and some parts manufacturers, to the United States. Quite likely, the assembly firms would have transplanted by the 1990s, even in the absence of trade protection, drawn by the advantage of skilled American workers and market proximity. But the coincidence of VRAs with the arrival of transplants strongly indicates cause and effect, delivering a surprise payoff to the US economy.

As figure 2.7 illustrates, the volume of assembled auto imports has held steady since the early 1990s, with occasional spikes and dips. Export volumes are much smaller but show a gradual increase. In constant dollar terms, assembled imports exhibit an upward trend, apart from the Great Recession (figure 2.8). With the North American Free Trade Agreement (NAFTA) and then the US-Mexico-Canada Agreement (USMCA), a larger share of assembled auto imports come from Mexico and Canada rather than Asia (but not shown in the figure).

22 Toyota’s Company History (accessed on December 9, 2020); “Honda Celebrates 40 Years of Manufacturing in America,” Honda Corporate News, September 10, 2019 (accessed on December 9, 2020); “Where are Nissans made?” Nissan Blog (accessed on December 9, 2020).
Figure 2.7
**US automobile trade in units, passenger vehicles and trucks, 1989–2020**

Note: Quantity of passenger vehicles and trucks based on Harmonized Tariff Schedule (HTS) 8703 and 8704.


Figure 2.8
**US automobile trade in value, 1989–2020**

Note: Quantity of passenger vehicles and trucks is based on Harmonized Tariff Schedule (HTS) 8703 and 8704.

Following the transplant phenomenon, debate over trade measures moved to the percentage of a finished auto made from US parts, the so-called “domestic content” requirement. In 1982 the UAW sought legislation requiring 90 percent domestic content for transplant firms selling more than 500,000 autos annually in the US market. Domestic content legislation was not enacted, probably because VRAs were periodically renewed. But domestic content—defined as made in North America and pegged at 62.5 percent—was a core feature of NAFTA, which entered into force in 1994. When NAFTA was renegotiated and became the USMCA in 2020, the North American content requirement was raised to 75 percent. As figure 2.9 shows, the value of parts imports in constant dollars has continued to rise, largely reflecting the integration of the US, Mexican, and Canadian auto industries. US auto parts exports have increased but more slowly.

After his election in 2016, President Trump pressured auto firms to build more plants in the United States, while loudly criticizing the European Union for its 10 percent auto tariff, compared to the US 2.5 percent rate (though he never mentioned the 25 percent US Chicken War tariff on trucks and pickups). As figure 2.10 shows, employment in both auto assembly and parts shows a long-term downward trend, with pronounced fluctuations corresponding to the financial crisis. Automotive employment is a big issue politically, since historically it pays well.

Trump called on Commerce Secretary Wilbur Ross to conduct a national security assessment of auto imports. The Commerce Department found that American-owned automotive R&D and manufacturers of engines and powertrains, electrification technology, autonomous driving, and other features are all critical to US national security. In particular, the “United States defense industrial base depends on the American-owned automotive sector for... technologies that are essential to maintaining our military superiority.” However, Trump did not act on the report.

By 2020 many trade restrictions had passed into history, although Trump’s repeated threats kept auto executives on the alert. All the major firms opposed national security tariffs on auto imports, and none were enthusiastic about the USMCA’s increase in North American content to 75 percent. The residual industrial policy has two remaining pillars: the domestic content requirement, mainly benefiting parts firms, and the 25 percent Chicken War tariff, ensuring that heavy trucks and pickup trucks will be made in North America. As figure 2.11 shows, the number of US-assembled autos has fluctuated over the past three decades without much trend, while the gross value of output for the entire sector has trended upward in constant dollar terms.

Looking to the future, it seems worth asking whether it will be critical for the United States to command the leading edge of vehicle production, whether in hybrids, electric vehicles, or self-driving vehicles. We have little doubt that this will be an objective of US industrial policy for the Biden administration or its successor if Asian or European firms appear to take the lead. Depending on the measures chosen, and the cost they impose on household consumers and business

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users, future analysts may conclude that Americans would have been better off if Washington had welcomed vehicle imports from abroad. But the automotive industry is so central to American life that an academic autopsy will not change the objective of future policy. More relevant will be suggestions—based on past experience in autos and other industries—of measures that stand a better chance of success at reasonable cost. Our concluding chapter offers recommendations.

Figure 2.9
**US auto parts trade, 1996–2020**

billions of constant 2020 dollars


Figure 2.10
**US employment in the automobile industry, 1990–2020**

thousands of employees

**Note:** All employees, monthly, seasonally adjusted.

Summary Evaluation and Brief Explanations

- **Has the US auto industry become internationally competitive?** Successful outcome for assembly = A; intermediate outcome for parts = B

  Success for US assembly operations is mainly due to the accelerated migration of Japanese and European manufacturing to the United States. The Detroit Three learned from foreign firms and sharply improved their own performance. No major firm seeks renewed protection. Assembled auto exports accounted for 9 percent of domestic production by value in 2019. Remaining trade measures are concentrated on parts, given the 75 percent North American content requirement. The UAW and parts producers strongly advocate domestic content. US auto parts exports accounted for 11 percent of domestic production by value in 2019, largely to US auto assembly operations in Canada and Mexico.

- **Did protection save jobs at a reasonable cost?** Successful outcome for auto assembly = A; intermediate outcome for auto parts = C

  At the height of protection, in the late 1980s, VRAs may have added $1.7 billion to the annual cost of US-produced compact autos. The employment gain was then about 1,234 workers (Hufbauer and Elliott 1994). Arithmetic suggests that the added cost may have amounted to $1.2 million per worker per year. This is now history, and autos assembled in the United States are no more expensive than comparable imports. Estimates are not available for the cost per job-year of domestic content requirements in NAFTA and the USMCA for auto parts, but we speculate that the cost may not exceed the annual wage.
• Did protection advance the technological frontier of auto production? Successful outcome for auto assembly = A; successful outcome for auto parts = A

Transplant Japanese and European firms brought new technology, including extensive use of robots and just-in-time inventories, to US auto assembly. (Just-in-time inventories were applauded until the COVID-19 pandemic interrupted supply chains.) The transplants also instructed parts suppliers on better manufacturing and quality control methods. As a result, parts production was substantially upgraded.

SEMICONDUCTORS

The scientific basis for transistors and semiconductors can be traced to the 19th century, but the first practical transistor owes to William Shockley, a researcher at Bell Labs, in 1947. Within a decade, four companies were making semiconductors—Shockley Semiconductor Laboratories, Sprague Electric, Motorola, and Fairchild Semiconductor (Fairchild was formed by eight disaffected Shockley employees) (Holbrook et al. 2000). Of these pioneer firms, only Motorola and Fairchild survived as semiconductor manufacturers, but in 1967 three key Fairchild employees—Robert Noyce, Gordon Moore, and Andrew Grove—left to form Intel Corporation.

Rapid technical progress, characterized by “Moore’s law” (the doubling of transistors on a microchip every two years), fostered exploding demand, enabling employment in the computer manufacturing industry to more than double, from 116,000 to 236,000, between 1960 and 1970.25

During the industry’s formative years, government procurement—principally by the Department of Defense and intelligence agencies—was a major source of demand and support (see Richard Levin’s chapter in Nelson 1982). Between the mid-1950s and mid-1960s the federal government purchased between 30 and 40 percent of US semiconductor production. By the late 1970s, that figure had dropped to 10 percent.26

In 1977 the Semiconductor Industry Association (SIA) was formed by the pioneers of the five leading US firms: Fairchild, Intel, Advanced Micro Devices, Motorola, and National Semiconductor, which together accounted for about 80 percent of US production. Subsequently other firms joined, such as Micron Technologies and Texas Instruments, and SIA continues to shape all US industrial policy initiatives affecting the industry.

At about the same time, Japan took a serious interest in the semiconductor industry. Realizing it was far behind US technology, from 1976 to 1979, with government guidance, Japan implemented the very large-scale integrated circuit project, coordinating Hitachi, Mitsubishi, Fujitsu, Toshiba, and five major electric companies. By the 1980s Japan was a technological leader for


26 In 1980 the DOD launched the very high speed integrated circuit (VHSIC) research program for military purposes, quite independent of civilian needs.
two industry staples, dynamic random-access memory (DRAM) chips and erasable, programmable read-only memory (EPROM) chips. In terms of sales, Japanese firms concentrated on high-volume, low-cost DRAM production. They were protected in the Japanese home market by vertical integration between semiconductor producers and users and opaque nontariff barriers (according to US allegations). The firms offered very competitive prices and captured more than half the world DRAM market.

Responding to the Japanese threat, in 1985 SIA and the US federal government made their first foray into industrial policy. SIA filed a Section 301 petition with USTR complaining about access to the Japanese market. In quick succession, Micron Technologies and other US firms filed petitions with the Department of Commerce alleging Japanese dumping of basic (64K) DRAM and EPROM chips. The Department of Commerce, for the first time, self-initiated an investigation into Japanese dumping of 256K and larger DRAM chips.

The trade component of US industrial policy had two prongs: opening the Japanese market to US producers and pursuing antidumping actions against Japanese sales in US and third-country markets (Irwin 1996).

The antidumping prong was not particularly successful, for reasons worth recounting:

• First, rapid technical progress (Moore’s law) meant fast upgrading of chips, and as antidumping measures were implemented newer generations were overtaking the market. Indeed, by the time the antidumping phase ended in 1991, most US firms, apart from Micron and Texas Instruments, had left the DRAM market, and the main DRAM competitors were Japan, Korea, and Taiwan.

• Second, to resolve dumping complaints without the imposition of penalty duties, in 1986 Japanese firms (guided by their government) agreed not to price chips below “fair market value” (FMV) when exporting to the United States or third markets. FMV was to be calculated for each firm by the US Department of Commerce. While this “suspension agreement” was intended to foster competition between Japanese firms, in practice it abetted cartel behavior (Tyson 1992, 113-18; Flamm 1989; Irwin 1996).

• Third, to correct what it saw as Japanese backsliding, in 1987 the Reagan administration imposed 100 percent tariffs on $300 million of Japanese exports, a shocking affront to a military ally. Surveillance by the Ministry of International Trade and Industry of Japanese exports stepped up, and prices firmed.

• Fourth, the resulting lift to semiconductor prices and profits of Japanese firms in the late 1980s was probably greater than the lift to US firms. One estimate suggests that the short-lived Japanese cartel may have added 2,300 workers in 1989 to US semiconductor employment (when DRAMs and EPROMs were a small fraction of the industry workforce), $835 million to the profits of Japanese firms—and $257 million to the profits of US firms (Hufbauer and Elliott 1994). The cost to US consumers during this period was about $1,200 million annually, or over $500,000 for each US job “saved” by the Japanese cartel.
Fifth and finally, in the wake of escalating DRAM prices, the antidumping phase was challenged by a coalition of chip users, the Computer Systems Policy Project (CSPP, led by IBM and Hewlett-Packard). Antidumping duties expired in 1991, despite SIA’s efforts (Irwin 1996).

The market opening prong of the 1986 policy called for the share of US firms in the Japanese market to rise from around 10 percent, prior to the suspension agreement, to “slightly above 20 percent” in five years. This commitment was recorded in a secret and ambiguously phrased side letter to the suspension agreement (Irwin 1996).

While the SIA Section 301 petition failed to identify explicit nontariff barriers, in 1984 US producers accounted for 55 percent of chip sales in Europe, and 47 percent elsewhere, but just 11 percent in Japan (Irwin 1996). To the surprise of some observers, by the 1990s US chip sales exceeded 20 percent of the Japanese market. At the time, this was widely heralded as a success for industrial policy. However, Douglas Irwin (1996) recorded a skeptical verdict, and Craig Parsons (2002) found that no effects on chip imports by Japan were attributable to the US-Japan Semiconductor Trade Agreement (STA). Kenneth Flamm (1996) and C. Fred Bergsten and Noland (1993) suggest that the STA and other factors such as the shift in demand for the semiconductors may have had some effect on the foreign market presence.

Figures 2.12 through 2.15 illustrate facets of US semiconductor production. With the digital boom in the 1990s employment rose, but it declined after 2000 as automation replaced workers in fabrication plants; the numbers have held steady for the past decade. Weekly earnings, however, continued to rise, from around $800 in 2000 to around $1,720 in 2019 (figure 2.13). Semiconductor production is essentially high-skilled assembly work, with moderate wages.

By value, the US share of world exports dropped from 24.3 percent in the mid-1990s to about 3.4 percent in 2019, owing to stiff competition from other producers, notably China, Taiwan, South Korea, and rest-of-world producers such as Singapore, Malaysia and Vietnam (figure 2.14). In addition, exports to Japan are a dwindling market for US semiconductor producers (figure 2.15).

A crude comparison of export and import unit values indicates that US semiconductor producers export advanced chips, while US semiconductor buyers import basic chips. The HS 10-digit codes for semiconductors (under HS8541 and HS8542) show an average export unit value in 2019 of $23 and an average import unit value of $5.
Figure 2.12
Employment in the US semiconductor industry, 1972–2019

thousands of employees

Note: Monthly data are seasonally adjusted and based on NAICS 334413.

Figure 2.13
Average weekly earnings in the US semiconductor industry, 1972–2020

US dollars

Note: 1972–2002 data are based on Standard Industrial Classification (SIC) 3674; 2007–20 data are based on North America Industry Classification System (NAICS) 334413. Data for 2003–06 are not available.
Figure 2.14

Note: Semiconductor trade data are based on Harmonized System code 8541 and 8542.
Sources: World Bank’s World Integrated Trade Solution (WITS) and Taiwan Bureau of Trade.

Figure 2.15
US semiconductor exports to Japan as percent of US semiconductor production, 1997–2019

Summary Evaluation and Brief Explanations

- **Did trade measures advance the international competitiveness of the US semiconductor industry?** Failed outcome for the antidumping phase = D; intermediate outcome for the market opening phase = B
  
  At its inception in the 1960s, in 1986 when trade measures were imposed, and in the decades since, the US semiconductor industry has led the world, confirmed by respectable US exports of advanced chips (indicated by the high unit value of exports). Stiff competition between US firms fostered the industry’s international competitiveness. However, while not intended, the antidumping phase of the 1986 suspension agreement strengthened Japanese firms more than American firms by enabling a Japanese cartel that raised prices and profits. The market opening provision of the 1986 STA required Japan to increase the share of foreign semiconductors in its market to 20 percent in five years in exchange for suspension of the Section 301 action. The result is cloudy. The US share in the Japanese chip market increased from 9 percent to 14 percent during the 5-year agreement and reached 20.2 percent in the fourth quarter of 1992 (Irwin 1996, Baldwin 1994). However, in 2018 the US exported $928 million of semiconductors to Japan—not a trivial number but accounting for only 2.2 percent of the $40.4 billion Japanese semiconductor market. Since 2001, semiconductor sales to Japan, as a share of US production, have steadily declined (figure 2.15). This reflects the decision of major semiconductor firms to move away from fabrication in the United States and concentrate on the design of advanced chips.

- **Did trade measures save jobs at a reasonable cost?** Failed outcome for the antidumping phase = D; successful outcome for the market opening phase = A
  
  The user cost per DRAM and EPROM job saved in the late 1980s, owing to higher prices enforced by the Japanese cartel, exceeded $500,000, well above the average annual wage under $20,000. The market opening phase enlarged US production and created new jobs, at no cost to consumers. However, since semiconductor production essentially requires high-skilled assembly workers, over time more jobs have moved abroad.

- **Did trade measures advance the technological frontier of semiconductor production?** Intermediate outcome for the antidumping phase = C; successful outcome for the market opening phase = A
  
  DRAMs reportedly accounted for 60 percent of Texas Instruments profits in 1988 and boosted Micron’s sales sixfold in 1986–88 (Irwin 1996). To be sure, DRAMs are far from the semiconductor frontier in 2021, but the two firms remain technological leaders to this day. Financial strength due to higher DRAM prices in the late 1980s may have carried the two firms through a difficult period. Other US firms were leaving DRAM production and probably derived little benefit from the price lift. EPROM prices for 1M chips were little affected by the antidumping phase, though there was some lift for the 256K chips. Japanese market opening temporarily increased sales for most US firms, marginally adding to their research budgets, thereby helping to maintain technological leadership.

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Postscript on Semiconductors

In 2021 semiconductors are again in the news, as a centerpiece of President Biden’s industrial policy. Led by Charles Schumer (D-NY), the Senate in early June 2021 passed a $252 billion bill, the US Innovation and Competition Act, to provide government funding for technology R&D. The bill includes $52 billion funding for semiconductor R&D, fabrication, and measures to relieve supply shortages. Our concluding chapter evaluates this contemporary application of industrial policy.

SOLAR PANELS

Federal support for solar panels—also called photovoltaic (PV) cells and, more technically, crystalline silicon photovoltaic cells (CSPV)—began with a National Science Foundation R&D program in 1972 and shifted to the Department of Energy (DOE) in 1977 (see the William Pegram chapter in Cohen and Noll 1991). Research grants for specific facets were awarded to various institutions (such as the Jet Propulsion Laboratory and Sandia National Laboratories), but the awards allowed for some competition between the grantees. In addition, demonstration grants were awarded to some 20 other institutions. At its height, in 1981, the DOE R&D program received $160 million in federal funds. But during the Reagan administration funding was slashed to less than $50 million annually, a minor sum compared to subsequent industrial policy measures. While the DOE R&D program made significant technical advances, photovoltaics were still far from commercially viable when Reagan entered the White House and they faced a pessimistic outlook.

Moreover, prior to Reagan, the Carter administration had essentially superseded the ill-fated R&D program with an industrial policy phase launched in 1978, when generous tax credits were deployed to accelerate residential and commercial installation of solar panels. But allocation of the credits did not discriminate between domestic and foreign manufacturing firms. Three decades later, huge federal loan guarantees were extended to domestic PV firms, most notoriously Solyndra (chapter 3 evaluates the Solyndra episode).

In a second phase of solar panel industrial policy, while installation tax credits continued, multiple “trade remedies” were imposed, beginning in 2012, to discourage solar cell imports and promote domestic manufacturing firms.

This assessment separately evaluates the tax credit phase and the trade remedy phase.

Tax Credit Phase

Long before trade measures dominated the industrial policy picture, President Carter’s Energy Tax Act of 1978 (part of his National Energy Act) provided temporary 10 percent tax credits for renewable energy installations: 10 percent of the cost of renewable energy installations could be deducted from federal taxes otherwise owed. The goal was to accelerate solar, wind, and geothermal alternatives to oil and gas, not to protect infant solar panel manufacturing firms. The centerpiece of the 1978 act was a gas guzzler tax; renewable energy was a side event. But Carter deserves credit (or blame) for inaugurating industrial policy for the adoption and manufacture of solar panels. The investment tax

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29 PV devices are capable of converting sunlight into electrical energy.
credit (ITC) incentive enacted in 1978 has been modified over time. While some tax credits for renewable technologies expired at the end of 2020, 10 percent credits for solar, wind, and geothermal installations remain as permanent.\(^{30}\)

Much later, the Energy Policy Act of 2005 created a two-year 30 percent ITC for commercial and residential PV systems, temporarily replacing the 10 percent credit. Like its 1978 predecessor, it did not discriminate between domestic and imported solar panels. The 2005 tax credit was extended multiple times at 30 percent, but in 2020 it was reduced to 26 percent and in 2021 to 22 percent. When it expires in 2022, unless again renewed, the 10 percent permanent ITC will be reinstated.

Until 2012, when the first trade remedies were applied, tax credits were the centerpiece of solar panel industrial policy. After 2012, trade protection came to dominate industrial policy for the manufacturing segment of the solar panel industry. In contrast, tax credits supported the entire solar panel industry—manufacture, distribution, and installation.

Total industry employment increased from 119,000 in 2012 to 250,000 in 2019.\(^{31}\) Creating manufacturing jobs was not the central goal of tax credits, but it is worth noting that, of total industry employment in 2012, about 75 percent were engaged in distribution and installation, while only 25 percent were engaged in manufacturing.

Figure 2.16 shows annual and cumulative installed solar cell capacity between 2007 and 2019, expressed in gigawatts (GW), while figure 2.17 depicts the levelized cost decline of solar energy, expressed in dollars per megawatt-hour (MWh). Installation uptakes and cost declines were both dramatic. By 2012, the levelized cost of solar energy had dropped to about twice the levelized cost of natural gas power (figure 2.17). By 2020, electricity from various fossil fuels cost between $0.05 and $0.17 per kilowatt-hour (kWh), while the cost of solar energy ranged between $0.03 and $0.06 per kWh and was trending down.\(^{32}\)

The key analytic question is how much of the rise in installed capacity and price decline can be attributed to the 10 percent and 30 percent investment tax credits enacted in 1978 and 2005. The earlier NSF research program had made technical advances, but solar panels were far from commercially attractive before the tax credit phase, which significantly stimulated demand. It’s no surprise that solar industry advocates pressured Congress to extend the 30 percent tax credit in 2008 and again in 2016. One estimate suggested that the ITC would create about 230,000 jobs by 2016 in the solar PV market.\(^{33}\) Others argued that the 30 percent tax credit for 8 years would leverage billions in high-tech innovation and project development, inspire startups to launch new products and services, and result in tens of millions of panels installed across America.\(^{34}\) Even discounting this enthusiasm, a good part of the accelerated installations in 2005–16 (figure 2.16) should be attributed to the 30 percent ITC. After all, it cut the out-of-pocket cost of installations by more than a third. The huge drop in levelized solar power costs can also be partly attributed to soaring installations as a consequence of “learning by doing.”


Figure 2.16
Annual and cumulative installed solar capacity, 2007–19

Annual solar capacity additions (GW)  Cumulative solar capacity (GW)

Utility-scale CSP  Commercial PV  Utility-scale PV  Residential PV

AC = alternating current; CSP = crystalline silicon photovoltaics; DC = direct current; GW = gigawatts; PV = photovoltaics
Note: PV is in GW_{DC} and CSP is in GW_{AC}. Bars show annual capacity (left axis). Shaded areas show cumulative capacity (right axis).
Source: Bolinger et al. (2020).

Figure 2.17
Levelized photovoltaics (PV) and wind power purchase agreement cost and levelized gas cost projections, 2009–20

2019 dollars/MWh

Solar average cost projection  Wind average price  Levelized gas cost projection

MWh = megawatts per hour
Note: Solar and wind prices are subject to power project agreements.
Source: Bolinger et al. (2020).
Trade Protection Phase

For the United States, more than 80 percent of solar panels are imported. The bound US tariff on solar panel imports is zero percent. Protection is imposed by special measures, antidumping and countervailing duties.

US antidumping duties on solar panels imported from China were first imposed in 2012, at rates between 18.8 percent and 31.7 percent, plus countervailing duties at rates between 14.8 percent and 16.0 percent. Thus in 2011 affected solar panel imports from China were 56 percent of total US solar imports; in 2012 they dropped to 33 percent of total US solar imports. In December 2014 another round of antidumping duties was imposed on solar panel imports from China and Taiwan, at rates between 27.1 percent and 78.4 percent for China, and between 11.5 percent and 27.6 percent for Taiwan. Chinese solar panels also faced countervailing duties at rates between 27.6 and 49.8 percent. Thus while in 2014 imports from China and Taiwan accounted for 56 percent of total US solar imports, they dropped to 34 percent in 2015. The 5-year sunset review for antidumping and countervailing duties concluded by maintaining penalty tariffs to deter a recurrence of dumping and subsidies.

In 2017 the US International Trade Commission recommended safeguard restrictions on imports from all countries in response to a petition by two US solar panel producers, Suniva and SolarWorld. Trump imposed a safeguard tariff, which started at 30 percent in 2018 and decreased by 5 percentage points for each year through 2021, on PV solar panel imports. The tariffs exempted the first 2.5 GW of imported solar cells per year that are assembled in the United States as well as imports from some developing economies. The safeguard tariff is scheduled to expire in February 2022.

In 2018 the US Trade Representative imposed 10 percent tariffs on solar panel imports from China as part of its Section 301 trade war against a wide range of Chinese products. In 2019 the rate was raised to 25 percent. Collectively, these multiple trade remedies amount to a concerted effort by the US government to sustain US solar panel manufacturers. In 2000 First Solar launched large-scale US manufacturing of solar panels at Perrysburg, Ohio. By 2020 the US solar panel manufacturing industry consisted of over 20 firms, of which the three leading

36 Bound tariffs are the maximum US rates committed in US schedules filed with the World Trade Organization.
firms (each with over 1,000 MW of annual capacity) are First Solar, Hanwha Q Cells (headquartered in South Korea, but producing in the US-based location), and Tesla.

It must be repeated that manufacturing currently accounts for only a seventh of total jobs in the US solar industry; the rest are engaged in distribution, installation, and maintenance. Since 2016, total industry employment has been roughly constant according to the Solar Foundation. In 2019 some 250,000 people were employed full-time in the industry, of which only 34,000 were engaged in manufacturing (figure 2.18). Most solar industry workers and firms are opposed to trade protection because it makes their key raw material more expensive. For this reason, the tax credits discussed above marshal a very different political coalition than trade protection.

Imports and exports of solar panels illustrate the dubious competitive position of US manufacturers. Solar panels come in many sizes, shapes, and compositions, and undergo rapid price changes, providing ample room for two-way trade—but US imports far exceed exports (figure 2.19). US exports of solar panels reached $1.7 billion in 2010 and then steadily declined to just $56 million in 2019. The value of US solar panel imports reached a peak of $8.3 billion in 2016, declined in the face of trade remedies over the next two years, and rebounded in 2019. In volume terms, however, imports steadily increased while exports dwindled. Whether measured in terms of value or volume, US solar panel manufacturers have not attained international competitiveness, despite massive trade protection.

As figure 2.20 shows, many countries have exported solar panels to the United States. Only China and Taiwan were hit with antidumping and countervailing duties, beginning in 2012 and 2014, respectively. But in 2018 most exporters faced US safeguard tariffs. Comparing imports between 2011 and 2020, China’s share dropped from 56 percent of total US solar panel imports in 2011 to 3.9 percent in 2020. Malaysia and Vietnam largely replaced China, accounting for 30 percent and 28 percent of US solar panel imports in 2020, respectively.

During the trade protection phase, the average US PV module price declined from $1.59/watt in 2011 to $0.41/watt in 2019 (figure 2.21). Even after the Section 201 safeguard duty was imposed, the US price continued to decline, but remained somewhat higher than global PV prices. BloombergNEF reported global monocrystalline silicon (c-Si) module prices at around $0.20/watt and multi-c-Si module prices at around $0.17/watt in the second quarter of 2020. With the benefit of protection, annual US PV module production increased to 1.8 GW in 2019, from 1.0 GW in 2017. This was largely due to more foreign investment in new module assembly facilities in the United States. Hanwha Q Cells, a South Korean company, and Jinko Solar, a Chinese company (the largest module producer in the world), opened new module-assembly facilities in the United States, and a Canadian company, Heliene, reopened a shuttered solar module facility in Minnesota.

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43 Hanwha Q Cells is headquartered in South Korea. The product is developed in German technology and innovation center and produced in various locations such as China, Malaysia, the United States, and South Korea.
Figure 2.18
US employment in solar industry by job type, 2010–20
thousands of employees


Figure 2.19
US solar panel trade, 2000–20
billions of constant 2020 dollars

Note: Solar panel data are based on US Harmonized Tariff Schedule (HTS) 10-digit codes 8541406015, 8541406020, 8541406025, 8541406030, 8541406035, and 8541406045.
Figure 2.20

US solar panel imports in 2011 and 2020, by country

Note: Based on US Harmonized Tariff Schedule (HTS) 10-digit codes 8541406015, 8541406020, 8541406025, 8541406030, 8541406035, and 8541406045.


Figure 2.21

US photovoltaic (PV) module imports, domestic production, and average unit price, 2006–19

Summary Evaluation and Brief Explanations

Tax Credit Phase

• Did tax credits advance the international competitiveness of the solar panel manufacturing industry? Failed outcome = D

Tax credits accelerated installation of solar panels, thereby contributing to a rapid decline in solar power costs. On this metric, the tax credits achieved their primary goals—greater energy security when OPEC crises dominated public policy, and replacement of fossil fuels when climate change became a leading issue. The evaluation here, however, focuses on solar manufacturing. Owing in large part to tax credits, the United States became the second largest solar panel market in terms of installation, accounting for 12.7 percent of the global solar PV market in 2017. However, US production accounted for just 2 percent of worldwide cell and module production in 2015, according to the International Energy Agency, and the imbalance between US solar panel imports and exports illustrates the weak competitive position of US manufacturing firms.

• Did tax credits create jobs at a reasonable cost? Successful outcome = A

In 2019 total solar panel industry employment was about 250,000 workers. The 30 percent tax credit reduced the delivered cost to solar panel users by 43 percent ($1.00/0.70 = 1.43$, the delivered cost without the tax credit). Assuming a demand elasticity of $-0.65$, the reduction in delivered cost on account of the tax credit may have added 70,000 to the industry labor force. According to the Internal Revenue Service, electric property tax credits claimed in 2017 were $1.6 billion. By division, tax credits amounted to about $23,000 per additional worker. With average wages about $45,000, the cost was around half the wage rate for each job created. About 80 percent of the jobs created were in distribution, installation, and maintenance and only 20 percent in manufacturing.

• Did tax credits (together with the earlier NSF research program) advance the technological frontier of solar panel production? Successful outcome = A

The technological breakthroughs in the solar industry were numerous, including the invention of PV materials, concentrating solar power, solar heating and cooling systems, flexible cells mounted on various surfaces, and floating panels. Rapid installation of solar panels, abetted by generous tax credits, provided financial fuel for innovations, both in the United States and abroad.

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48 Solarfeed, “Top 10 Technological Breakthroughs in the Solar Industry 2019,” August 10, 2019 (accessed on January 12, 2021). Concentrating (or concentrated) solar power (CSP) technology concentrates sunlight to generate thermal energy, which is then used to generate electricity.
Trade Protection Phase

- Did trade measures advance the international competitiveness of the solar panel industry? Failed outcome = D

- Did trade measures save jobs at a reasonable cost?
  Intermediate outcome = B
  By 2019 the onslaught of trade remedies created an average ad valorem tariff equivalent of almost 29 percent on US solar panel imports. In contrast, the average US MFN tariff (the bound tariff) on US solar panel imports is almost zero. Owing to trade protection, US solar panel prices were raised by 22 percent. In turn, higher production added about 2,600 manufacturing jobs to the industry. This figure aligns with the Solar Energy Industries Association (SEIA) estimate that about 2,000 new solar manufacturing job were created by the 2018 safeguard measures. The median pay per solar panel production worker in 2019 was $45,120 per year, about 13 percent above the national median for all workers. The calculated 22 percent increase in solar panel prices cost purchasers about $125 million in 2019. Hence the cost per additional production worker was about $47,000, a little higher than the average wage.

- Did trade measures advance the technological frontier of solar panel production? Failed outcome = D
  Trade measures significantly offset price reductions from technology breakthroughs and slowed the pace of solar adoption. For example, the SEIA claimed that the safeguard measures implemented in 2018 came at the expense of 10.5 GW of lost solar deployment and $19 billion in lost investment. By retarding installations, the trade measures took away part of the financial fuel for innovations.

SUMMING UP

Analysis of impacts in four US industries—steel, textiles and apparel, semiconductors, and solar panels—shows that trade protection has not been a winning formula for industrial policy, judged by the twin tests of establishing an internationally competitive industry and saving jobs at a reasonable cost to household and business consumers. The main reason, of course, is that sunset industries have been more successful in obtaining trade protection; sunrise industries rarely appeal for new tariffs or quotas. To be sure, trade protection may mitigate the pain of job displacement, but when trade protection endures for a decade or longer, new workers will replace those who retire or quit, thereby prolonging the adjustment process. Economists have offered better

50 Ibid.
approaches, but the American political system evidently prefers off-budget protection that conveys a doubtful promise of industrial revival to meaningful adjustment assistance.

On the other hand, trade measures that open foreign markets can succeed, measured by classic tests. Opening foreign markets has historically been a central objective of US trade policy, though in the Biden administration so far labor and environmental objectives enjoy higher priority. While few negotiations lead to such dramatic opening as the Japan semiconductor case, nearly any reduction of foreign barriers will benefit US firms through incrementally greater sales and new jobs, at no cost to household or business consumers.

REFERENCES


3 Industrial Policy Through Subsidies Targeted to Specific Firms

INTRODUCTION

To make a splash, political leaders sometimes choose to concentrate public funds on a single entity, often newly created. If the venture succeeds, the political leader will be acclaimed. In 1933, amid the Great Depression, President Franklin Roosevelt created the Tennessee Valley Authority (TVA) to bring flood control, cheap electricity, and better agricultural practices to an impoverished region covering most of Tennessee and parts of six other states. A pillar of Roosevelt’s New Deal, TVA was a huge success economically and politically (Kline and Moretti 2014).

Two landmark projects, both technological wonders, are often cited as models for industrial policy: the Manhattan Project (atomic bomb) and the Apollo Mission (moon shot). And the Electronic Numerical Integrator and Computer (ENIAC) project during World War II contributed to the US lead in computational power. Military and space projects, however, may have little regard for cost and are not intended to meet the test of the market. TVA, though distant in time and not a technological pathfinder, and far grander in scope than the projects examined in this chapter, is more relevant.

Unlike the first three episodes covered in this chapter—the Synthetic Fuels Corporation, Solyndra, and Crescent Dunes—the TVA applied known technology. In that respect only, it bears a similarity to the fourth, fifth, and sixth episodes: the Mercedes-Benz plant in Alabama, the Chrysler bailout of 1980, and the Foxconn Wisconsin plant. The objective of the first three cases was technological breakthrough; the objective of the second three cases was creating or preserving jobs.

SYNTHETIC FUELS CORPORATION

The Synthetic Fuels Corporation (SFC) was launched in 1980 at the tail end of President Carter’s tenure, almost as a coda to his sweeping National Energy Plan (NEP). The NEP, designed to tackle the energy crisis, was announced in April 1977. Characterized by President Carter as the “moral equivalent of war,” the NEP had five major components (Congressional Budget Office 1977):

51 Despite the success of the TVA, efforts to bring similar programs to other depressed regions, such as the Delta Regional Commission, have received little financial support and never succeeded.

52 We did not evaluate competitive government subsidy programs, such as the Small Business Innovation Research program, and it seems likely that some of them can claim successful records.
• It would gradually deregulate US oil and gas prices, which were kept well below world levels by price controls enacted by President Nixon in 1971.

• It entailed new taxes to capture the difference between regulated and deregulated prices.

• The revenue would be devoted to energy independence projects, foremost coal gasification (this was well before carbon emissions rose to the top of the political agenda).

• Tax revenues would also be used for better insulation for homes and public buildings, and for solar energy tax credits.

• Gas-guzzler autos would face new taxes, and all autos were potentially subject to a “standby” gasoline tax of 50 cents/gallon.

Energy crises in 1973 and 1979 were the driving force for the NEP (figure 3.1). As Americans faced long lines for gasoline, they felt at the mercy of OPEC and supported “energy independence” as a public policy goal. President Nixon was the first to make the call, echoed by President Ford; President Carter followed their lead.

**Figure 3.1**

*Global crude oil prices, 1950–2019*

US dollars per barrel

![Graph showing global crude oil prices from 1950 to 2019 with marked energy crises in 1973 and 1979.]

*Source: BP Statistical Review of World Energy, “Oil: Crude Prices since 1861.”*

When Carter’s NEP reached the Senate, the president was outmaneuvered by Senator Russell Long (D-LA), wily chair of the Senate Finance Committee, and the National Energy Conservation Policy Act, signed in November 1978, was a pale reflection of the NEP (Schipper et al. 1979). Oil and gas taxes were gone, as were gas-guzzler and standby gasoline taxes. However, the Energy Department was given broad authority to issue fuel efficiency regulations.

After this setback, in the wake of the 1979 oil crisis, Carter turned his attention to producing energy at home. The Energy Security Act of 1980 comprised separate acts calling for the establishment of a government-funded Synthetic Fuels Corporation as well as funding in the following areas: biomass
energy and alcohol fuels, renewable energy resources, solar energy and energy conservation, geothermal energy, and ocean thermal energy conversion.

The Synthetic Fuels Corporation was tasked with extracting oil from shale rock at reasonable cost. Shale oil is nothing new—it was used as a fuel in prehistoric, ancient, and medieval times. European and American firms tried industrial production of shale oil, using heating retorts, in the 19th century, but US shale firms were put out of business by the 1859 discovery of crude oil in Pennsylvania.

Yet despite the rapid growth of crude oil production, numerous shale oil ventures made a comeback early in the 20th century and again during the First and Second World Wars. The 1973 oil crisis prompted the US Navy to take a fresh look at shale oil, and throughout the 1970s major oil firms such as Occidental Petroleum, Shell, Exxon, Sun Oil, and Phillips opened shale oil plants on Colorado’s Western Slope and nearby sites.

Thus, the Synthetic Fuels Corporation was launched in 1980 on the back of a long history of shale oil experience and at a time when the energy crisis was uppermost in American politics. A more auspicious timing for industrial policy is hard to imagine. But the downfall was swift.

Like other shale oil developments stretching back to the 19th century, the core idea was to extract oil from shale by applying heat to shale either in situ or mined in heaps. The SFC would not build its own plants but instead proceed in joint ventures with private firms. As sideline activities, it would finance coal mines and transportation facilities, and promote alcohol fuels, solar energy, and fuel from urban waste (Campagna 1995, 143). But its main task was shale oil.

However, only a small sum was committed to shale projects in the form of loan guarantees and the purchase of synthetic fuel at prices far above market levels. Over its six-year life, the SFC—capitalized at $20 billion ($63 billion in 2020 prices)—had budget outlays of only $1 billion, directed to shale projects that failed, and $400 million on a defaulted coal gasification loan.53 The company’s two main shale ventures, both in Colorado, were a Union Oil (Unocal) project at Parachute Creek and a Colony project backed by Exxon at Piceance Basin. Both loan guarantees were approved in October 1980 and neither defaulted. A solicitation for additional bids in December 1980 attracted 61 proposals by March 1981, more than half for coal liquification and gasification. Only a few were funded, and those at modest levels.

The creation of the SFC sparked a private shale boom in the Western Slopes, and several small towns doubled or tripled in population. High pay—$16 an hour when the prevailing wage was about $6—attracted workers to the shale operations. When the Colony project closed on May 2, 1982 (“Black Sunday”), some 2,500 workers were laid off.54 When the Unocal project (the last one operating) shut down in 1991, another 685 workers lost their jobs.55 Thus, the SFC can be credited with creating about 3,200 direct jobs during the life of the Colony and Unocal projects.

The Unocal project entailed capital outlays of $650 million. The Colony project cost Exxon $300 million to purchase its 60 percent interest from Atlantic Richfield in 1980, and over the next two years Exxon (and Tosco) spent another $400 million on the project, meaning that total capital outlays reached $700 million. This was a small fraction of the $5.5 billion estimated for completion of the Colony plant and wisely never spent. All told, the SFC generated less than $1.4 billion of private capital outlays ($4.4 billion at 2020 prices) (Limerick and Hanson 2009).

After President Reagan took office in January 1981, SFC officers and board membership turned over several times, and no further shale ventures were approved. Oil prices declined, and by 1983 all the private firms except Unocal had closed their operations. Reagan terminated the SFC in the Omnibus Budget Act of 1985.

Summary Evaluation and Brief Explanations

• Did shale oil become internationally competitive? Failed outcome = D
  Despite the abundance of shale oil, retort technology was not a winning approach. Hydraulic fracturing (“fracking”) was practiced experimentally in 1947 and applied on numerous oil and gas wells over the next 40 years. But not until the late 1980s did George P. Mitchell introduce a commercially successful technique at a cost of $6 million: horizontal drilling with multiple stems from the same vertical shaft. The retort ventures supported by the SFC were never commercially viable.

• Did the SFC create jobs at a reasonable cost? Failed outcome = D
  As industrial policy ventures go, the SFC was remarkably cheap, spending about $1 billion on shale oil during its short life ($3.2 billion at 2020 prices). Associated private firms created about 3,200 direct jobs for two years, of which about 700 lasted another nine years (until Unocal shut down in 1991). All told, about 9,500 job-years were created thanks to SFC loan guarantees. Thus, the potential taxpayer cost was about $105,000 per job-year, well above the prevailing wage (about $32,000) on the Colorado Western Slope. This figure does not count the money lost by Unocal and Exxon. However, the loan guarantees were never defaulted. In any event, the SFC did not launch a viable industry; that awaited Mitchell and horizontal hydraulic fracturing.

• Did government assistance advance the technological frontier of shale oil production? Failed outcome = D
  Retort technology was the wrong approach in the SFC era. At a future date, it might become viable, but not owing to the SFC.

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SOLYNDRA CORPORATION

As anxiety about climate change pushed to the forefront of US political issues in the 1990s and 2000s, interest grew in solar energy as part of the solution. According to a poll by the Pew Research Center, support for policies on environment, global warming, and climate change sharply increased after 2011. Respondents who answered that climate change policy should be prioritized rose to 52 percent in 2020, from 29 percent in 2014 (figure 3.2). Concurrently, solar energy costs declined substantially (figure 3.3), following private improvements from the mid-1970s to late 2000s that dramatically dropped the cost of solar panels from $77 per watt to less than $2. As well, the price of natural gas (figure 3.4), the main competitor of solar energy, decreased significantly.

Figure 3.2
US support for prioritizing policy on protecting the environment and dealing with global climate change, 2008-20

Solar energy has ancient origins. Egyptians used magnifying glasses to start fires in the 7th century BCE, and Greeks and Romans harnessed solar power for religious ceremonies. Fast forward, French scientist Edmond Becquerel discovered the conversion of light to electricity in 1839. But commercial conversion of solar energy to electricity only came a century later with the invention of silicon photovoltaic cells by Daryl Chapin, Calvin Fuller, and Gerald Pearson at Bell Labs in 1954.

When the Obama administration entered office in 2009, it inherited a financial crisis. The government responded with a massive stimulus program, the American Recovery and Reinvestment Act of 2009 (ARRA), which had an initial budget of $787 billion, as well as huge Treasury and Federal Reserve assistance to Wall Street firms. Tucked into the ARRA was a loan guarantee program administered by the Department of Energy (DOE). Solyndra Corporation, established in 2005, was the first recipient, with a federal guarantee of $535 million, enabling it to borrow from private lenders.

Over time, DOE extended loan guarantees to multiple energy firms, starting with programs authorized by the Energy Policy Act of 2005, later augmented by
other acts (Cunningham and Eck 2021). The DOE’s Loan Program Office (LPO) currently has open-ended loan guarantee authority exceeding $43 billion, of which $35 billion has been extended. Solyndra was the outstanding failure that cost public money to pay creditors, but loans also defaulted in two other cases. While the overall loss rate on LPO projects is under 3 percent and no other losses are as spectacular as those of the Solyndra case, an important qualification is in order (Bopp 2020).

As reported by Chris Edwards at a congressional hearing in 2017, many LPO projects entail loans to firms that have guaranteed contracts to sell power at generous feed-in tariff rates to utilities, which pass the higher cost to household and business ratepayers. Power contracts are thus a major component of industrial policy finance for the renewable energy sector. In 2016, 21 of the 30 LPO projects enjoyed guaranteed revenue streams under long-term power contracts and 29 states required such purchases of renewable energy (Bopp 2020). Lacking such backing, Solyndra’s failure was an exception to the overall LPO record.

Solyndra offered a different solar energy technology from the dominant flat silicone panels. Solyndra’s invention was copper indium gallium selenide (CIGS) thin film, rolled into one-inch diameter cylinders, with 40 cylinders packed in a one-meter by two-meter panel. Solyndra began producing CIGS solar cells in September 2010 at its Fab 2 plant in Fremont, California. Whatever their technical merits, the CIGS solar cells were overwhelmed, almost at their introduction, by a drastic fall in the price of flat silicone panels. Between 2009 and mid-2011 the price of polysilicon, the key ingredient for flat panels, dropped by almost 90 percent. Massive Chinese subsidies were at play, both because China wanted its own renewable energy and because Beijing saw an opportunity to dominate the global market. At the same time, as mentioned above, the price of natural gas—a competing energy source—fell sharply with the spread of hydraulic fracturing.

Solyndra filed for bankruptcy in September 2011 and laid off 1,100 employees. The Treasury lost $528 million on its loan guarantee. A fraction of the amount was offset by $52 million collected from two Chinese firms in price-fixing litigation, leaving the net federal loss at about $476 million. Financial irregularities by Solyndra and its chief executives were later the subject of federal investigations.

Summary Evaluation and Brief Explanations

• Did CIGS solar cells become internationally competitive? Failed outcome = D
  The dramatic fall in the price of polysilicon, coupled with technological improvements in flat panels, ended any prospect for CIGS solar cells.

• Did Solyndra create jobs at a reasonable cost? Failed outcome = D
  Like the SFC, Solyndra was remarkably cheap as industrial policy ventures go, costing about $476 million during its short life ($552 million in 2020 prices). While operating, it employed 1,100 workers for about two years, indicating a cost per job year of about $216,000, far above the prevailing wage between $27,500 and $48,000.\(^6^5\)

• Did federal support advance the technological frontier of renewable energy production? Failed outcome = D
  CIGS solar cells were the wrong technology, given the drop in polysilicon prices and advances in flat panel technology. Other solar projects, evaluated elsewhere in this study, had considerable success.

**CRESCENT DUNES**

A pervasive problem with solar energy is the absence of power at night and during cloud cover. One storage technology, concentrating (or concentrated) solar power (CSP), stores solar energy in a fluid such as synthetic oil or molten salt. When power is needed, the hot oil or salt is exposed to tubes containing water to create steam, driving conventional turbines to produce electricity. This system was pioneered in Spain, which has several CSP plants capable of generating 2.3 gigawatts of solar power.\(^6^6\) The DOE provided loan guarantees for several CSP projects in 2010 and shortly after.

Compared with photovoltaic (PV) solar cells, the big advantage of CSP is that it can deliver power 24 hours a day, whereas PV must be complemented with another energy source at night or during cloud cover; the alternative energy source is often natural gas for conventional turbines. The big disadvantage of CSP is cost: Per kilowatt-hour, the combination of PV and natural gas delivers electric power at a fraction of the CSP cost. Of course, natural gas emits carbon, about half the amount of coal-fired power per kilowatt of electricity, but much more than carbon-free CSP.

Among its CSP projects, the DOE provided a loan guarantee of $737 million to finance Crescent Dunes in September 2011. The 110 megawatt Crescent Dunes plant, located in Tonopah, Nevada, applied a novel technology: concentrating solar heat at the top of a 640-foot tower filled with molten salt. The heat is gathered by a circular array of 10,347 heliostat mirrors that track the sun and focus the heat to a receiving plate and then down to the molten salt. Hot salt that passes over water tubes creates steam to drive a conventional turbine. By contrast, the Spanish CSP design entails a series of parabolic troughs with receiver tubes filled with hot transfer fluid that creates steam to drive the turbine.

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Crescent Dunes commenced power production in February 2014, never achieved more than 20 percent of advertised capacity, and ceased operation in October 2016. The project was beset with problems, the most immediate being a leak in the molten salt tower. It was criticized by environmentalists for destroying the natural beauty of the Mojave Desert and depriving endangered desert tortoises of their habitat. The heliostat mirrors were said to blind passing aircraft pilots, and the glowing red receiving plate was regarded as an eyesore. More fundamental was the high cost of Crescent Dunes power: $135 per megawatt-hour (MWh), compared to $33/MWh from a PV solar farm and $38/MWh for combined-cycle natural gas power.\(^67\)

In July 2020 the controlling sponsor, Tonopah Solar Energy, filed for bankruptcy, and Judge Karen Owens approved the winding up plan in December. According to the *Wall Street Journal*, the cost to taxpayers, including both loan guarantees and a refundable tax credit, amounted to $510 million. Overall construction cost was around $1 billion, implying that private investors lost an additional $500 million.\(^68\)

While Crescent Dunes was the clearest failure among DOE CSP ventures, the department’s other projects also have problems. The department has supported 1.8 gigawatts of CSP power capacity, including the Ivanpah Solar Electric Generating System (392 MW, three power towers), Mojave Solar One (280 MW, parabolic troughs), Solana (250 MW, parabolic troughs), and Genesis Solar (250 MW, parabolic troughs). Most are operating well below capacity and environmental complaints are common. The National Renewable Energy Laboratory issued a CSP report in January 2019 forecasting a drop in the CSP levelized cost of energy (LCOE)\(^69\) from $210/MWh in 2010 to $50/MWh for baseload power in 2030, a big improvement but still above the foreseeable levelized cost of PV power (Murphy et al. 2019).

Creating jobs was not an objective of Crescent Dunes or other CSP projects, but the Department of Energy expected Crescent Dunes to create 600 construction jobs (for about 2 years) and 45 permanent jobs.\(^70\) Likewise, other CSP projects were front-loaded in terms of construction jobs.

**Summary Evaluation and Brief Explanations**

- **Is the Crescent Dunes CSP technology internationally competitive?**
  - **Failed outcome = D**

  Power tower CSP technology has an inferior performance record compared to parabolic CSP technology. The parabolic systems performed much better than Crescent Dunes, but overall, CSP systems are inferior, from a cost standpoint, to PV solar fields coupled with combined-cycle natural gas turbines.

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\(^69\) The LCOE describes the cost of solar power per kWh over the system life. Roughly speaking, LCOE is calculated by dividing the capital cost of the solar power plant by expected lifetime production (usually over 25 years) expressed in kWh. A more accurate calculation considers maintenance costs and the time value of money.

\(^70\) Crescent Dunes CSP project (accessed on September 9, 2021).
• Did Crescent Dunes create jobs at a reasonable cost? Failed outcome = D
  Creating jobs was not an objective of the Department of Energy in supporting CSP projects, but the Crescent Dunes project apparently created about 1,200 job-years of construction employment (600 jobs for 2 years) and 90 job-years of permanent employment (45 jobs for two years). The public subsidy was $510 million, indicating a taxpayer cost of almost $400,000 per job-year created. At the time, construction jobs paid about $48,000 per year.  

71 According to the Bureau of Labor Statistics, average hourly earnings of construction workers were $25.19 in 2010.

• Did federal support advance the technological frontier of renewable energy production? Failed outcome = D
  Conceivably, some variant of CSP technology will produce renewable electricity at a competitive cost, but the power tower approach seems very unlikely.

MERCEDES-BENZ IN ALABAMA

At least five southern states have attracted auto manufacturers with tax breaks, free land, new roads, and other concessions. No major auto assembly plant has been built in the past 40 years without a bidding war between states. For example, Kentucky won the bidding competition for Toyota’s first plant in the United States, expecting that the $800 million plant would employ about 3,000 workers in the 1970s (Black and Hoyt 1989). Each state hopes to secure auto jobs that pay better than prevailing local wages. Similar competition between states characterizes plant location decisions in other industries, from semiconductor chips to aircraft to Amazon fulfillment centers. This type of state-level industrial policy characterizes hundreds of cases since 1970, by far the most numerous. To illustrate this type of policy, we examine the case of Mercedes-Benz in Alabama.

Studies give at best limited support to the effectiveness of such state initiatives.  

A recent report found some evidence of direct employment gains from attracting a firm but not strong evidence that firm-specific tax incentives increase broader economic growth at the state and local levels (Slattery and Zidar 2020). Research showed that only 15 percent of the firms participating in an economic development incentive program in Texas would have invested in another state without this incentive (Jensen 2017). And analysis revealed that business incentives such as tax credits do not have a large correlation with a state’s unemployment or income levels, or future economic growth (Batik 2017).

Turning to the Mercedes-Benz case, in 1993 tax breaks and other subsidies attracted the firm to locate an assembly plant in Vance, Alabama, near Tuscaloosa and Birmingham. Apart from targeted subsidies, Alabama offered a right-to-work environment. The total cost of the original incentive package to taxpayers was estimated at $253 million (Crowley 2015), including $12.4 million for site preparation and an estimated $50 million in improved infrastructure. Through bonds, the state and Tuscaloosa County provided $43 million and $11 million for plant construction, respectively. The state also built a training
facility with an annual $5 million subsidy. The subsidies approximately equaled the cost of the initial plant, which was much expanded over the next 20 years.

When it started production in 1997, Mercedes employed 1,500 workers as it pledged; by 2020, the number was about 4,200.\footnote{Made in Alabama (Alabama Department of Commerce), “How Mercedes Is Preparing for the Future in Alabama”; and Chris McFadyen, “Mercedes Closing Sedan Production in Alabama,” Southern Automotive Alliance, July 21, 2020.} Average pay at Mercedes in 2020 was $60,400, while average pay across Alabama was $54,000.

At its inception, the Mercedes deal was sharply criticized by other Alabama firms for benefits they did not enjoy, and by citizens for money that might have been spent on education and social services. Governor Jim Folsom lost his reelection bid partly because of Mercedes. But as spillover effects multiplied with the arrival of automotive suppliers and other firms, the Mercedes deal came to be viewed as a huge success and in time redounded to the benefit of Alabama’s political leaders.

Given its eventual political success, the subsidy cost per job is worth exploring. When announced, the Mercedes deal was reckoned to be the high-water mark of auto subsidies, near $200,000 for each job initially created. This figure was 18 times what Tennessee paid for a Nissan plant in 1980 and more than 7 times what it paid for the GM Saturn plant in 1985, 4 times what Kentucky paid for a Toyota plant in 1985, and 3 times what South Carolina paid for a BMW plant in 1992. If Alabama’s industrial policy to attract Mercedes can be counted an economic success, then much lower state subsidies in other auto plant bids, and hundreds of cases in other industries, should be scored as economic bargains.

Thus, the subsidy cost per Mercedes job is worth exploring, as well as alternative economic history. Taking the $250 million figure for subsidies, the cost per job was $167,000. However, the original 1,500 Mercedes jobs lasted more than two decades. If we assume that, at its inception, the conservative prospective life of the Mercedes plant was just 10 years, then the subsidy cost per job-year was just $16,700. In 1997 the average Mercedes wage was around $50,000. Even ignoring the subsequent expansion of Mercedes and its spillover attraction to other industrial firms, the deal easily passes our test for the taxpayer cost per job-year, so it’s not surprising that kindred industrial policy incentives, at lower subsidy costs per job-year, prove irresistable to state governors and legislators.

Conceivably Mercedes-Benz might have located in Alabama without the state subsidy, but that seems highly unlikely given competitive bids from other states. Of course, even without Mercedes-Benz, Alabama land and labor would have found alternative, if less prominent, employment, and the same is true of many industrial policy projects in other states. But alternative economic history, relying on market forces, often carries little weight with elected governors.

However, alternative economic history with a different use of state funds is worth considering. In 1993 Alabama median household income was $43,000 (US median, $53,800), making it the 46th ranked state; in 2018 the Alabama median was $49,900 (US median, $63,200), making it 47th.\footnote{See US Bureau of Labor Statistics Table H-8, Median Household Income by State: 1984 to 2018 at 2018 US dollar terms.} Whatever impact Mercedes and spillover plants exerted in the Tuscaloosa/Birmingham region, they were unable to improve the state’s ranking.
The Alabama corporate tax rate in 1993 was 5 percent, raised to 6.5 percent in 2019, compared to North Carolina, which cut its corporate tax rate from 7.8 percent to 2.5 percent. Devoting $250 million to the university system in 1993, especially STEM programs, or to a general corporate tax cut, might have made more difference to median household income, but not with the same political splash.

As table 3.1 shows, median household income in nominal dollars increased by 106 percent in Alabama between 1993 and 2019, slightly faster than North Carolina. However, employment growth was just 20 percent in Alabama, compared to 40 percent in North Carolina. Meanwhile, Alabama raised its corporate tax rate and increased its corporate tax revenue much faster than North Carolina, which cut its corporate rate. Texas exceeded both states in household income and employment growth and had no corporate tax. Based on these aggregate measures, state industrial policy in Alabama was not more successful than North Carolina and was decidedly less successful than Texas. Of course, both North Carolina and Texas practiced their own versions of industrial policy.

### Table 3.1
Economic performance in Alabama, North Carolina, and Texas, 1993 and 2019

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<th>North Carolina</th>
<th>Texas</th>
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<td>1993</td>
<td>2019</td>
<td>1993</td>
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<td>Corporate income tax rate (percent)</td>
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<td>Corporate income tax revenue (millions of dollars)</td>
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</tbody>
</table>

#### Summary Evaluation and Brief Explanations

- **Is Mercedes-Benz in Alabama nationally competitive?**
  
  **Successful outcome = A**
  
  The goal of Mercedes in the Alabama factory was to produce for the US market, not the world market. For that reason, the applicable competitive test is the national market. The Mercedes share of the US luxury auto market has done well: its market share increased from 0.42 percent in 1993 to 2.09 percent in 2020 (figure 3.5), outcompeting Lexus and BMW.

- **Did the industrial subsidy create jobs at a reasonable cost?**
  
  **Successful outcome = A**
  
  The startup subsidy of $250 million, averaged over 10 years of Mercedes employment, works out to about $16,700 per job-year, well below our threshold of the state average annual wage in 2020, $54,000. By
this criterion, many state industrial policy initiatives are successful at creating jobs. However, our criterion does not consider alternative uses of public funds.

• **Did the industrial subsidy advance the technological frontier of auto production?** Intermediate outcome = B

Since Mercedes Alabama started production in 1997, several new models have been added to its lineup. These represent the best engineering Mercedes can bring to auto production.

### Figure 3.5

**Annual US sales by Mercedes-Benz, 1948–2020**


### CHRYSLER BAILOUT OF 1980

Chrysler began its corporate life in 1913 as Maxwell Motors, was taken over by Walter Chrysler in 1925, and gradually enlarged as a multinational producer of cars, tanks, and other products. But in the 1970s, everything seemed to go wrong. Gasoline prices spiked, curbing demand for Chrysler’s specialty, big cars. Fierce competition from Germany and Japan captured much of the US market for smaller, fuel-efficient autos. Record inflation was answered by Paul Volcker’s record interest rates, which crushed demand for housing and consumer durables, including autos. By 1979 these forces brought Chrysler, one of the big “Detroit Three” auto firms, to the verge of bankruptcy.

In May 1980 US Treasury secretary G. William Miller approved a federal loan guarantee of $1.5 billion, conditioned on Chrysler raising an additional $2 billion from investors, banks, or state and local governments. At the time, this was the largest bailout in US history. Miller justified the bailout based on “a public interest in sustaining [Chrysler’s] jobs and maintaining a strong and competitive national automotive industry.”75 According to the Congressional Budget Office,

some 360,000 Chrysler workers would have lost their jobs in bankruptcy, plus additional disruptions in supplier industries.\textsuperscript{76} In return for the loan guarantee, the US government received from Chrysler 14.4 million warrants to purchase Chrysler stock at $14 a share, good until 1990. In 1983 Chrysler repaid the guaranteed loans and repurchased the warrants at auction from the US government. The loan guarantee program thus generated revenues for the US government.\textsuperscript{77}

The charismatic president of Chrysler, Lee Iacocca, quickly turned the firm around by closing plants, laying off workers, and cutting wages by about $3 an hour compared to other automakers. Under his leadership, the company launched a series of fuel-efficient, front-wheel drive vehicles (so-called K-cars) and minivans in 1980.\textsuperscript{78} Iacocca’s efforts were assisted by a strong national economy and low inflation in the 1980s. Chrysler earned record profits of $2.4 billion in 1984.

Compared to the far smaller bailout of Lockheed in 1971 (loan guarantee of $250 million), and the far larger bailout of financial institutions plus Chrysler and GM in the wake of the 2008–09 Great Financial Crisis (the Troubled Asset Relief Plan enabled loan guarantees of $80 billion for the auto industry), the Chrysler bailout of 1980 entailed rather small federal costs. In fact, the only material cost was the hypothetical loss of Treasury revenue if the loan guarantee had been used to finance a higher-paying venture.

More important, in the realm of alternative history, is what might have happened if bankruptcy had taken its course, enabling new firms to reassemble the pieces of a vanquished corporate giant. Most observers believe the alternative scenario would have ended badly,\textsuperscript{79} (although at least one respected scholar, Daniel Ikenson, strongly favored the bankruptcy option in the context of the Great Financial Crisis).\textsuperscript{80} Whatever the merits, we do not attempt to calculate the costs or benefits of alternative scenarios.

**Summary Evaluation and Brief Explanations**

- **Is Chrysler nationally or internationally competitive? Successful outcome = A**
  
The primary goal of the federal loan was to rescue Chrysler from bankruptcy and ensure its survival in the domestic market. During the 1980s the United States experienced a surge of auto imports from Japan and Europe. But Chrysler’s market share grew after the loan program was introduced in 1980 (figure 3.6).

- **Did the guarantee save jobs at a reasonable cost? Successful outcome = A**
  
  With the federal loan guarantee of $1.5 billion to save about 360,000 employees from at least temporary disruption, the cost per job saved was about $4,600, if the loan had defaulted. Compared to the average annual wage of $23,289 for workers in the auto manufacturing industry in

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\textsuperscript{78} NPR, “Examining Chrysler’s 1979 Rescue,” November 12, 2008.

\textsuperscript{79} Peter Behr, “When the Taxpayers Saved Lee Iacocca’s Bacon, What Did They Get Out of It?,” Washington Post, May 13, 1984.

\textsuperscript{80} Daniel Ikenson, “Bailouts Beget More Bailouts,” Cato Institute, June 16, 2011.
1985, the taxpayer exposure per job saved appears cheap. Moreover, the loan was repaid without taxpayer funds, and the Treasury actually made money on the warrants.

- **Did the guarantee advance the technological frontier of auto production?**
  
  **Successful outcome = A**
  
  Considering that Chrysler subsequently produced more fuel-efficient models, the federal guarantee contributed to a significant technological advance. If Chrysler had entered bankruptcy, it seems highly unlikely that it would have carried out the R&D or had financial resources to produce fuel-efficient models.

**Figure 3.6**

**Chrysler’s market share in the United States compared with GM and Ford, 1970–90**

![Figure 3.6](https://knoema.com/infographics/flosile/top-vehicle-manufacturers-in-the-us-market-1961-2016)


**FOXCONN WISCONSIN**

Foxconn Technology Group, a multinational corporation based in Taiwan, is best known for producing Blackberries and iPhones and for its factories in China. It also produces dozens of electronic products for a long list of major firms and has factories in more than 20 countries. In 2017, amid fanfare, Wisconsin governor Scott Walker and Foxconn CEO Terry Gou announced a $10 billion display panel manufacturing plant in Mount Pleasant, Wisconsin, that would eventually employ 81

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81 Hourly earnings in the automobile manufacture sector were $12.13 in May 1983. See “Wages at motor vehicle plants outpaced those at parts factories,” *Monthly Labor Review*, May 1, 1985.
13,000 workers. The state of Wisconsin committed up to $3 billion in subsidies, conditioned on performance benchmarks. At the time this was the largest state subsidy to a foreign firm in US history.

The Foxconn Wisconsin project soon ran into strenuous objections based on environmental and cost concerns, and from residents in Mount Pleasant who vigorously opposed condemnation of their homes to create the four-square-mile site. The unpopular project was a factor in Walker’s loss of the 2018 gubernatorial election. In response, Foxconn dramatically reduced the scale of the project and changed the product mix to focus on servers, 5G networking gear, and a data center. In April 2021 a new agreement with Wisconsin reduced the planned Foxconn investment to $672 million, the creation of 1,454 new jobs, and tax credits of just $8 million. By that time, however, the state had spent $90 million on roads related to the factory, while Mount Pleasant and Racine County had committed to $911 million in upgrades for sewer, water, electrical systems, and other infrastructure to support the project. All told, the state and local subsidy for Foxconn will be about $1 billion.

While the downsized project will emphasize engineers and researchers, rather than a manufacturing workforce, it will probably not advance the frontier of electronic technology. Most Foxconn products are manufactured to specifications supplied by its customers, such as Apple, Blackberry, Cisco, Google, Hewlett-Packard, Huawei, Intel, and Lenovo. The customers, not Foxconn, are the technology pioneers.

Summary Evaluation and Brief Explanations

- **Did the subsidy make Foxconn nationally or internationally competitive?**
  Intermediate outcome = C
  As a global company that produces high-tech electronic products in more than 20 countries, Foxconn was already internationally competitive prior to the Wisconsin subsidy. Nor is there evidence that the subsidy will make Foxconn more attractive to its name brand customers.

- **Will the industrial subsidy create jobs at a reasonable cost?**
  Intermediate outcome = B
  As of June 2021, no job was created in Foxconn facilities, while about $1 billion of state subsidy was consumed in building infrastructure. If 1,454 jobs are eventually created, with a tenure of 10 years, total job-years for the project will be about 14,500. The subsidy cost per job year would then be about $69,000, less than the average wage of engineers and other professionals. However, that scenario is based on conjecture.

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84 Corrinne Hess, “Another new plan, but will Foxconn follow through this time?” AP, March 6, 2021.
• Will the industrial subsidy advance the technological frontier of electronic products? Failed outcome = D
  As a contract manufacturing firm, Foxconn relies on the technology of its high-tech customers.

SUMMING UP

Federal subsidies for one or two firms in search of pioneering technologies often fail, based on the first three episodes reviewed in this chapter. One reason, of course, is that pioneering technologies are risky endeavors, and failures are a common experience. A second reason is that focusing federal money on just one or two firms inevitably forecloses alternative business and scientific leaders and discovery paths. Competitive pressure is also reduced, if not eliminated. For this reason, when seeking pioneering technologies, it seems better to subsidize competition between several firms.

On the other hand, federal or state subsidies targeted to a single firm that applies known technology stand a good chance of succeeding, based on the test of establishing or reviving an enterprise at a reasonable cost per job created or saved. The Chrysler rescue in 1980 illustrates a revival that saved 360,000 jobs at a cost of less than $5,000 per job-year. Similarly, in the wake of the global financial crisis of 2008–09, both General Motors and Chrysler-Fiat were rescued by federal subsidies, along with several Wall Street financial firms. None of these cases entailed a search for pioneering technology. Likewise, the Mercedes-Benz episode in Alabama and the Foxconn episode in Wisconsin—emblematic of dozens if not hundreds of state incentives offered to lure thriving firms with known technologies—succeeded in creating local jobs at a reasonable cost per job-year. That said, most of the jobs created in the subsidizing state probably came at the expense of jobs that might have been created in rival states, and quite possibly at the expense of alternative jobs in the home state.

REFERENCES


4 Industrial Policy through Public and Private R&D

INTRODUCTION
This chapter examines six industrial policy cases centered on research and development (R&D), and the results for several US firms. In these six cases, creating or saving jobs was a secondary or tertiary goal. Advancing the technological frontier was the primary objective, to enhance US leadership. A seventh case, with the flavor of industrial policy but a very different orientation, is North Carolina’s Research Triangle Park, where research was conducted and paid for by private firms, with background support from the state. Lee Branstetter and Mariko Sakakibara (2002) showed that consortium outcomes are positively associated with the level of potential R&D spillovers in the consortium, a finding supported by the case studies offered in this chapter.85

DEFENSE ADVANCED RESEARCH PROJECTS AGENCY (DARPA)

Without question, DARPA is the US model for frontier industrial policy. The agency, housed in the Defense Department, was created by President Dwight Eisenhower to maintain US military superiority following the Soviet launch of Sputnik in 1957. By design, DARPA’s staff is small and operates by awarding R&D grants to academic and industry partners. Grant decisions are made by about 100 DARPA program managers who are scientifically trained, insulated from political pressure, and mandated to fund high-risk, high-reward R&D. Program managers enjoy a three- to five-year tenure.

Other federal departments sought to emulate DARPA’s success, even using similar names: HSARPA for Homeland Security in 2002, IARPA for the intelligence agencies in 2006, and ARPA-E in the Department of Energy (DOE) in 2009. None of these had the budget or achievements of DARPA, but they emulated aspects of its operations (Azoulay et al. 2018). President Biden proposes to add ARPA-H to the National Institutes of Health (NIH) with a budget of $6.5 billion to investigate cancer, diabetes, and Alzheimer’s, and to add ARPA-Climate to DOE alongside ARPA-E, giving the two units a combined budget of $1 billion, up from $427 million for ARPA-E alone.86

DARPA has avoided congressional criticism and in fact has won plaudits from the Government Accountability Office (GAO 2015) and Congressional Research Service (CRS), which summarized the key institutional features of the DARPA model that ensure its success (Gallo 2020). While many R&D projects fail, a few succeed in spectacular fashion. At its inception, DARPA funded R&D with both

85 Noland (1996) suggests that “Japan is found to have a comparative advantage in goods intensive in total, privately funded, and applied R&D activities, and a comparative disadvantage in publicly funded and basic R&D intensive goods.”

military and commercial applications; in 1973 Senator Mike Mansfield (D-MT) sponsored an amendment that confined DARPA to military projects. As a rule, these are classified, but many have commercial spillovers.

We make no comment on purely military research sponsored by DARPA, beyond observing that the United States maintains a wide margin of technological superiority over its Russian and Chinese adversaries. DARPA accounts for about a fifth of the Defense Department’s research budget (Gallo 2020), and probably deserves more than a fifth of the credit for US superiority. As for commercial projects, both direct and spillover, DARPA’s outstanding research contributions deserve mention. This list omits purely military achievements, which account for a larger share of breakthroughs in recent decades.

- Weather satellites (1959)
- Materials science (1960)
- Global satellite navigation (1960)
- Information processing (1962)
- Computer mouse (1964)
- “Mother of all Demos” – video transmission (1968)
- Explosive metal forming (1968)
- Arpanet, precursor to the internet (1969)
- Glassy carbon, used in surgical implants (1971)
- Gallium arsenide for semiconductor chips (1972)
- Ceramic turbines (1975)
- Metal oxide semiconductor implementation service (MOSIS) for very large scale integration (VLSI) (1981)
- Miniaturized GPS receivers, now used in cell phones (1983)
- Sematech (1987)
- High-definition systems, used in TVs (1989)
- Wafer-scale semiconductor integration (1989)
- Microelectromechanical systems (MEMS) (1994)
- Revolutionary prosthetics (2006)
- Autonomous vehicles (2007)
- Massive data analysis (2008)
- Spectrum collaboration challenge event (2019)

For the past two decades DARPA’s budget has held steady, in 2019 constant dollars, at about $3.5 billion per year. Since 1991 DARPA’s cumulated budget totals about $98 billion, again in constant 2019 dollars.\textsuperscript{87}

\textsuperscript{87} Department of Defense R&D by Military Department, 1991-2020 provides the annual budget of DARPA (accessed on May 20, 2021).
While DARPA’s objective was not to create either jobs or shareholder wealth, a few comparisons are apt. Concentrating on the internet, and ignoring DARPA’s contributions to information processing, massive data analysis, and much else, the payoff from five prominent businesses—Facebook, Amazon, Apple, Netflix, and Google (FAANG, in financial circles)—is spectacular. In 2019 these five companies together employed about 1.1 million workers at very high pay,\textsuperscript{88} and their combined share of market value was $3.9 trillion. Giving DARPA just 5 percent of the credit for these numbers translates into 55,000 jobs and $195 billion in shareholder wealth.

Summary Evaluations and Brief Explanations

In this study of US industrial policy episodes, DARPA earns an A+.

- **Did DARPA projects help make US tech firms internationally competitive?**
  
  **Highly successful outcome = A+**
  
  Many US tech exports of goods and services can be traced in part to DARPA R&D projects. Trade balances may not reflect the competitive prowess of US tech firms, since many of them produce abroad for sale in the United States, but they do reflect the competitive strength of US production, an obvious concern for public officials. Until 2000, US exports of tech goods were larger than imports, but in 2019 US tech exports of goods were just 70 percent of US tech imports (and US nontech exports of goods were only 64 percent of nontech imports). Persistent large merchandise trade deficits are a fact of the American economy, but the somewhat smaller tech deficit indicates revealed comparative advantage for this sector. Moreover, US intellectual property (IP) royalties amounted to $43 billion in 2019, another indicator. A large share of these royalties represents tech-related IP royalties and fees. While many tech exports, such as medical equipment, have little connection to DARPA R&D, others are directly related, such as semiconductors, materials, and GPS products.

- **Did DARPA projects create jobs at a reasonable cost?**  
  **Highly successful outcome = A+**

  As a generous figure, we attribute $10 billion of DARPA’s cumulative 1991–2020 budget of $98 billion (in constant 2019 dollars) to the cluster of internet technologies (DARPA 2020). Based on that assumption, here is a speculative calculation. During the next decade, assuming FAANG jobs are constant at 1.1 million annually, and attributing just 5 percent of those jobs to DARPA R&D, some 55,000 job years can be credited to DARPA (ignoring jobs created in all other sectors). Based on this arithmetic, the cost for each FAANG job-year created was around $20,000, far below the average wage in FAANG firms. Of course skeptics can argue that the internet was waiting to be discovered, and within a short time would have emerged without DARPA. On the other hand,

\textsuperscript{88} Google and Facebook offer entry-level salaries at $181,000 and $188,000, respectively. Kif Leswing, “Here’s how big tech companies like Google and Facebook set salaries for software engineers,” CNBC, June 15 2019.
the pool of internet beneficiaries is far larger than FAANG firms, so even if DARPA only accelerated the internet by two years, the job-years created in Amazon, eBay, and other firms far exceed our estimate.

- Did DARPA advance the US technological frontier in multiple industries?
  
  Highly successful outcome = A+

  Across a broad range of commercial activities, DARPA made spectacular contributions. It also helped secure US technological superiority in multiple military arenas.

RENEWABLE ENERGY

In the wake of oil shocks in the 1970s, President Carter promoted an energy plan aimed at reducing consumption of petroleum, converting shale and coal to oil and natural gas, and increasing the use of coal in the American energy menu. At the time, renewable energy was an afterthought; as global warming has risen in the political agenda, so has public support for solar and wind energy. The early objective was to supplement domestic oil and gas supplies, but as carbon emissions came to be identified as an environmental villain, the goal shifted: reduce the use of coal, oil, and gas and increase renewables. Over four decades (1978–2018), DOE funding for renewable energy technology research and development amounted to about $28 billion (in constant 2016 dollars), accounting for 18 percent of the department's total energy R&D outlays (Clark 2018). Lynn Cunningham and Rachel Eck (2020) summarize dozens of federal programs designed to further renewable energies, not only solar and wind but also biomass, geothermal, hydrogen, and other sources. Here we limit our discussion to solar and wind programs administered by the DOE.

The Solar Energy Technologies Office (SETO) and Wind Energy Technologies Office (WETO) were created by the Energy Policy and Conservation Act of 1975 and have been successively renewed. Over the past 45 years SETO has been authorized a total of about $7.6 billion and WETO about $2.4 billion (in constant 2019 dollars). SETO partners with industry, national laboratories, and universities to bring reliable and affordable solar energy technologies to market, financing R&D in five major programs: photovoltaics (PV), concentrating solar power (CSP), systems integration for solar technologies, balance of systems cost reduction, and technology to market. WETO forms partnerships with federal, state, and other stakeholder groups to conduct R&D activities through competitively selected, cost-shared projects carried out by private firms to improve the performance, lower the cost, and accelerate the deployment of wind energy technologies.

Public R&D was not the only public support that propelled the adoption of wind and solar energy. The DOE Loan Program Office (LPO) guaranteed loans of numerous renewable energy projects, including a few spectacular failures (e.g., Solyndra, discussed in chapter 3). Nevertheless, the overall loss record on approximately $35 billion of loan guarantees as of December 31, 2020, was just 3.3 percent of total disbursement, or about $1 billion.89 This figure must be added to the R&D outlays.

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Also to be considered are “feed-in tariffs” (FIT), which require electric utility firms to pay high prices for solar and wind energy generated by independent firms and, in some cases, by residential households. For example, participants in Dominion Virginia Power’s voluntary FIT program received $0.15/kWh for five-year contracts in 2013, when the average retail electricity price in Virginia was $0.105/kWh and $0.078/kWh for residential and commercial customers, respectively. Without support from LPO loan guarantees and feed-in tariffs, solar and wind energy could not have made the inroads to electric power depicted in figure 4.1.

Figure 4.1
Annual capacity additions of different generator types, 1998–2019

gigawatt percent

Source: Bolinger et al. (2020).

Moreover, it seems likely that “learning by doing” (Arrow 1962) added significantly to the technological advances enabled by SETO and WETO programs as well as private R&D.

Adding together public R&D for SETO and WETO ($10 billion), DOE loan guarantee losses ($1 billion), and assuming $0.15/kWh for FIT programs (approximately $2.5 billion for 20 years), total taxpayer and consumer costs of renewable energy support since 1975 amount to about $13.5 billion.

Taking a holistic approach (not trying to parse the contribution of various public supports) we compare the overall cost of federal and state support with the benefit from reduced carbon emissions, on the assumption that wind and solar energy supplanted electricity from fossil fuels. Figure 4.2 shows that fossil fuel emissions of carbon dioxide (CO$_2$) between 1973 and 2020 averaged around

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5 billion metric tons per year. Assuming a 3 percent discount rate, Nordhaus’s DICE model suggests that the average social cost of CO₂ emissions was $47 per metric ton of CO₂ in 2020 (estimates from two other models were $23 and $84).\(^{91}\)

Figure 4.2

Total carbon dioxide emissions from fossil fuels, 1973-2020

Cumulative wind and solar power generated between 1984 and 2019 was about 2,530 billion kWh. During the same period, annual average electricity generated by fossil fuels was 2,486 billion kWh, and annual average fossil fuel emissions of CO₂ were 5.4 billion metric tons.\(^{92}\) On average, 1 billion kWh generated from fossil fuel electric power plants produced about 0.002 billion tons of CO₂ emissions (calculated by dividing 5.4 billion metric tons of CO₂ emissions by 2,486 billion kWh generated by fossil fuels). Applying the Nordhaus figure of $47 per metric ton, the cumulative 2,530 billion kWh of renewable energy reduced about 5.49 billion tons of CO₂ emissions, for a total social cost saving of $258 billion.

Creating jobs was never the primary goal of renewable energy programs. However, according to the US Energy & Employment Report (NASEO & EFI 2020), the total number of electric generation jobs (manufacture, distribution, installation, maintenance) was 896,800 in 2019. About 27.7 percent of these jobs were in solar and 12.8 percent in wind, indicating about 363,000 jobs in renewable energy. Assuming that renewable jobs were one-third that number in 2010, and then increased in a linear manner, over a decade about 2.4 million renewable job-years were created.

International export data suggest that the United States performs poorly in renewable energy products relative to its major competitors, particularly China

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\(^{92}\) Electricity generation and CO₂ emissions by source are from the US Energy Information Administration. See annual and monthly energy reviews (accessed on May 20, 2021).
and the European Union (figure 4.3). Of course, all of them subsidize wind and solar, and that distorts trade figures. The vast export disparity nonetheless suggests that US manufacturers of solar and wind products are far behind their competitors. US wind turbines experienced export growth until 2013, and then declined to less than $2 billion in 2020 (figure 4.4), whereas US imports of wind turbines have grown exponentially since 2013.

Figure 4.3
Exports of renewable energy products by country/region, 2001–20

Source: APEC list of “environmental goods” (including solar panels and wind turbines) in 2015; Trademap.org via UN Comtrade (accessed on July 2, 2021).

Figure 4.4
US trade in wind turbines and parts, 1989–2020

Note: Data are based on HTS841290, HTS850231, and HTS850300; may include nonwind related parts.
Summary Evaluations and Brief Explanations

- **Did renewable energy projects help make US renewable energy firms internationally competitive?** Failed outcome = D
  The United States is heavily dependent on imports of environmental goods, particularly in solar energy. In 2019 EU exports of environmental goods grew to $184 billion while US exports remained under $60 billion (figure 4.3). However, it must be emphasized that the social benefits of reduced carbon emissions ($258 billion), using the Nordhaus figure of $47 per metric ton, substantially exceed the total US taxpayer and consumer cost of renewable energy supports ($13.5 billion).

- **Did renewable energy projects create jobs at a reasonable cost?** Successful outcome = A
  Cumulative SETO and WETO R&D budgets (in constant 2019 dollars), plus DOE loan losses and FIT costs over 20 years, were estimated at $13.5 billion. To this figure we should add about $12 billion for cumulative investment tax credits for renewable energy installations between 2008 and 2020 (Joint Committee on Taxation, various years), giving a total public outlay of $25.5 billion. During the decade 2010–19, about 2.4 million total job-years were created in renewable energy, indicating a cost per job-year of around $10,600. Since the 2019 median annual wage in solar and wind energy is estimated at about $50,000,3 the public outlay per job-year is by far smaller than the average wage.

- **Did renewable energy projects advance the US technological frontier?** Successful outcome = A
  While the European Union and China are highly competitive in creating and deploying renewable energy technologies (IRENA 2019), the United States has significantly advanced its own technological frontier. Federal and state incentives contributed to the growth of US renewable energy as domestic firms invented frontier electric battery technology (for electric vehicles) and dramatically cut the cost of installed solar and wind energy.

**SEMATECH**

The Sematech story contains three episodes of industrial policy. First, and most important, was creation of the public-private consortium located in Austin, Texas, and named after its objective, SEmiciconductor MAnufacturing TECHnology. This episode, funded by DARPA, lasted from 1987 to 1997. Second, the state of Texas provided funding on a much smaller scale between 2004 and 2010. Overlapping the Texas episode of industrial policy, the state of New York began extending grants to Sematech in 2003, and with larger grants lured the consortium to the SUNY Polytechnic Institute campus in Utica in 2010. But after several reorganizations and declining state support, Sematech is now a shadow of its former self, with an annual operating budget under $3 million. This case study is limited to the first episode of industrial policy, federal support, with passing accounts of the Texas and New York episodes.

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3 A study reported that 2019 median hourly wages in solar and wind energy generation are estimated at $24.48 and $25.95, respectively. See E2 (Environmental Entrepreneurs), *Clean Jobs, Better Jobs: An examination of clean energy job wages and benefits*, October 2020 (accessed on August 29, 2021).
In the second half of the 1980s Washington was alarmed by Japan’s growing dominance in the semiconductor industry, crowding out US firms. One policy response was the US-Japan Semiconductor Trade Agreement, examined in chapter 2. While federal R&D support, with an eye to military needs, was an enduring feature (see the Levin chapter in Nelson 1982), the other policy response was Sematech.

At the time, the US semiconductor industry consisted of about 70 firms, many of them small (Irwin and Klenow 1996). There were three rationales for the Sematech policy: first, that sharing R&D between companies would avoid costly duplication; second, that US firms suffered from a common problem, expensive and slow manufacturing processes; and third, that the phenomenon of technology spillovers justified federal support.

At its outset, Sematech was a nonprofit partnership between the federal government and 14 US semiconductor firms (mainly the most successful), out of an industry total of 71 firms (Irwin and Klenow 1996). It did not design chips and was banned from selling semiconductor products. The National Defense Authorization Act allowed DARPA (then called ARPA) to contribute $100 million annually and the 14 firms provided a matching amount, on a sliding scale based on each firm’s sales (minimum annual fee $1 million, maximum $15 million).

In addition, to draw the partnership to Austin, the state of Texas made a one-time contribution of $62 million. The participating firms were called on to send their own R&D personnel to Austin for “tours of duty” of one to three years, bringing between 100 and 200 skilled engineers at a time. Robert Noyce, an Intel founder and acclaimed pioneer, was the initial CEO. The 14 firms enjoyed “club” benefits such as early access to better equipment, fabrication factory designs, and defect controls, as well as spillovers from “people-to-people interaction” (GAO 1990, Irwin and Klenow 1996). The fact that the consortium initially consisted of 14 US semiconductor companies meant that the other 57 US firms were denied early access to club benefits. In the 1990s three of the initial firms (LSI Logic, Micron Technology, and Harris Corporation) left the consortium.

In a widely cited study, Douglas Irwin and Peter Klenow (1996) explored the difference between consortium members and nonmembers to examine Sematech’s impact on R&D outlays, profits, investment, and productivity. Their strongest finding was that Sematech reduced R&D outlays by members relative to nonmembers. Evidently, consortium members saw some substitutability between their own R&D and findings shared through Sematech. In a later econometric study, Kenneth Flamm and Qifei Wang (2003) argued that R&D sharing did not detract from Sematech’s payoff in terms of bolstering the US industry. As for the other performance variables examined by Irwin and Klenow (1996), no significant differences were found between consortium members and nonmembers.

DARPA supported Sematech to the tune of $870 million (Sargent, Gallo, and Schwartz 2018). Job creation in Sematech’s Austin office was not the goal. Rather, the goal was to slash semiconductor manufacturing costs and thereby spur industry sales and jobs. Two of Sematech’s accomplishments during its DARPA decade were to reduce the R&D expenditure required for each new generation of chip miniaturization and to compress the miniaturization cycle from three years to two.

Figures 4.5 and 4.6 show semiconductor employment and sales figures during the decade of DARPA support. No one would claim that Sematech alone
was responsible for the industry’s comeback. Two other events were decisive. First, consolidation concentrated the industry’s sales and R&D into six big players: Intel, Texas Instruments, Motorola, Advanced Micro Devices, National Semiconductor, and Micron (table 4.1). Concentration meant less duplication in the industry’s own R&D budget.

**Figure 4.5**

**US employment in semiconductors and related devices, 1972–2020**

Thousands of jobs

The period in yellow indicates when DARPA funded Sematech (1987–97)

**DARPA = Defense Advanced Research Projects Agency**
**Note:** Annual average data are based on NAICS 334413 and not seasonally adjusted.
**Source:** US Bureau of Labor Statistics.

**Figure 4.6**

**Value of US exports of semiconductors and related components, 1990–2009**

Billions of dollars, seasonally adjusted

Table 4.1
Key semiconductor firms in the United States in 1989

<table>
<thead>
<tr>
<th>Firm</th>
<th>Employment</th>
<th>Net income (millions of dollars)</th>
<th>Sales (millions of dollars)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Motorola</td>
<td>104,000</td>
<td>498</td>
<td>9,620</td>
</tr>
<tr>
<td>Texas Instruments</td>
<td>70,000</td>
<td>292</td>
<td>6,522</td>
</tr>
<tr>
<td>Intel</td>
<td>22,000</td>
<td>391</td>
<td>3,127</td>
</tr>
<tr>
<td>National Semiconductor</td>
<td>32,200</td>
<td>(23)</td>
<td>1,648</td>
</tr>
<tr>
<td>Advanced Micro Devices</td>
<td>13,072</td>
<td>46</td>
<td>1,605</td>
</tr>
<tr>
<td>Micron</td>
<td>3,000</td>
<td>106</td>
<td>446</td>
</tr>
</tbody>
</table>


Second, the industry shifted from low-margin DRAM memory chips (increasingly made in Japan, Korea, and Taiwan) to high-margin microprocessors. That said, comments by industry leaders indicate that Sematech helped reduce manufacturing costs, through both in-house R&D and grants to equipment firms. For example, Intel executives said the firm reduced production costs by $200–$300 million in exchange for its annual Sematech investments of about $17 million.94 As a speculative assumption, we attribute just 10 percent of the industry’s job growth between 1987 and 1997 to Sematech’s contribution, in other words, about 3,000 jobs (jobs in 1987 were 242,700 and in 1997 they were 272,900, indicating a gain of about 30,000 jobs).

Before evaluating the federal support episode of industrial policy, it’s worth summarizing the Texas and New York experiences with industrial policy. For the period between the end of federal support (1997) and the start of Texas support (2004), Sematech depended solely on industry contributions. At the same time, it became less restrictive in terms of foreign connections and less exclusive with respect to nonmembers. If sharing R&D were a winning proposition for competing firms, Sematech would have thrived (and similar consortia would have been created in other industries). That did not happen, and Texas stepped in with support. After 2004, Texas extended grants and loans of $80 million to Sematech and promised a “good faith effort” to raise another $120 million, which never materialized, probably because leading semiconductor firms were losing their enthusiasm for the consortia approach.

New York proved the stronger suitor for Sematech: in 2002 it lured a branch operation with $160 million of incentives and in 2007 it gave $300 million for the whole enterprise. During the New York episode of industrial policy, Sematech branched out to areas beyond manufacturing technology—such as green technology, power electronics, and biotechnology—and attracted a few foreign firms, notably Taiwan Semiconductor Manufacturing Corporation.

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(TSMC). The consortium, however, continued to lose industry members, notably Samsung Electronics and Intel. In 2015 Sematech was merged with SUNY Polytechnic Institute.

Summary Evaluations and Brief Explanations

- **Did Sematech help make US semiconductor firms internationally competitive?**  
  **Intermediate outcome = C**
  In an early analysis, Robert Byron (1993) was skeptical that Sematech deserved any credit for the industry’s success in the late 1980s and early 1990s. Much later (2011), however, a glowing issue of the *MIT Technology Review* credited Sematech with revitalizing the US semiconductor industry.\(^{95}\) Figure 4.6 shows that US exports of semiconductors reached a peak in 2000, suggesting that DARPA funding increased US competitiveness for a period of time. But export gains did not persist. Leading US firms concentrated on design rather than fabrication, leaving production to foundries abroad. Taiwanese and Korean semiconductor firms, led by TSMC and Samsung, soon dominated global markets for semiconductors. Commenting on current congressional plans for major subsidies to the industry, T. J. Rodgers, former chair of the Semiconductor Industry Association (SIA), authored an op-ed very critical of Sematech’s contribution to US competitiveness.\(^{96}\)

- **Did Sematech create jobs at a reasonable cost?**  
  **Intermediate outcome = B**
  DARPA provided Sematech with total funding of $870 million between 1987 and 1997. Semiconductor job creation, attributing 10 percent to Sematech, was about 3,000. Applying simple arithmetic, the cost per job-year created by Sematech was about $29,000. At that time, the average annual wage in the semiconductor fabrication sector was about $27,000.

- **Did Sematech projects advance the US technological frontier?**  
  **Successful outcome = A**
  In the early 2000s US firms like Intel and Texas Instruments were world leaders. Manufacturing technology was improved by shared production techniques under Sematech auspices. Sematech did not turn the United States into an export powerhouse for semiconductors (that role is claimed by Taiwan and Korea), but it did improve production techniques at a critical moment.

**FLORIDA’S BIOTECH REGION**

In 2003 Florida Governor Jeb Bush personally went to La Jolla, California, to woo Scripps Research Institute to open a Florida biotech branch.\(^{97}\) Armed with what was then a stunning sum of $310 million in state funds and the political advantage of being the president’s brother, he persuaded nonprofit Scripps to set up a life sciences research campus near the town of Jupiter in Palm

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97 Andy Reid, “Scripps Research Institute’s opens [sic] Florida complex; was tax investment worth it?” *South Florida Sun-Sentinel*, February 25, 2009.
Beach County, on the Atlantic coast between Miami and Orlando. The county augmented the state funds (some obtained from federal grants) with $290 million for land, improvements, and buildings, bringing the total for Scripps to $600 million.\textsuperscript{98}

Three years later, in 2006, Sanford Burnham Prebys Medical Discovery Institute, also based in La Jolla, was persuaded to follow Scripps, this time to Orlando, Florida, with state and county funding (half and half) of $310 million. Over the next decade and a half other life science firms moved to the Jupiter area, often with state or county support, such as the Max Planck Neuroscience Institute (2010) and Beacon Pharmaceutical Jupiter (2019).\textsuperscript{99} In 2020 Florida claimed that 260 biotech companies were operating in the state. As with suppliers to Mercedes-Benz in Alabama, it would be fair to say that many of these firms were drawn from other states, rather than adding to the national stock of biotech expertise. In any event, we confine this industrial policy episode to Scripps and Sanford Burnham.

Scripps started operations in Florida 2009, and by 2014 had 545 employees. In 2020 the number of full-time employees was 423, counting faculty members and staff.\textsuperscript{100} Graduate students complement the faculty. In 2017 the Nature index ranked the Scripps Institutions in California and Florida first among nonprofit life science institutes worldwide, and in 2020 they were ranked third. Many faculty members are internationally acclaimed scientists, and a few are Nobel Laureates. Scripps Florida has attracted multiple grants from the National Institutes of Health and from private foundations, such as the Bill and Melinda Gates Foundation, Pew Charitable Trusts, and W.M. Keck Foundation.

An economic study commissioned by Scripps concluded that, cumulated over a 15-year period, Scripps Florida generated $3 billion in additional state income.\textsuperscript{101} The study used a multiplier of 2.42 for secondary effects and made other optimistic assumptions. Even applying a large discount factor to this estimate, the Scripps Florida venture appears to have paid off in economic terms—state income generated exceeded state and county subsidies by a healthy margin.

Sanford Burnham started operations in 2008 but closed in 2015 for lack of sufficient federal funding. It repaid the state $12 million and transferred its buildings to the University of Central Florida to establish a cancer research and treatment facility.\textsuperscript{102} At its inception Sanford Burnham committed to create 300 jobs, but it did not achieve more than 260.\textsuperscript{103}

\textsuperscript{98} Florida governor Ron DeSantis, “Scripps Florida” (accessed on August 17, 2021).
\textsuperscript{99} Sam Howard, “Jupiter’s new bioscience biz: How will it work, what will it do?” Palm Beach Post, February 7, 2020.
\textsuperscript{100} See Scripps Florida Annual Report 2020 (accessed on August 17, 2021).
\textsuperscript{102} Naseem S. Miller, “UCF officially takes over the Sanford Burnham building, will transform it into cancer research facility,” Orlando Sentinel, December 1, 2018.
Summary Evaluation and Brief Explanations

• Is Florida’s biotech center internationally competitive?
  Successful outcome = A
  International competitiveness for this episode cannot be measured by conventional trade statistics. However, acclaim and post inception grants to Scripps Florida more than outweigh the closure of Sanford Burnham. Moreover, subsequent biotech arrivals, especially the Max Planck Neuroscience Institute and the Beacon Pharmaceutical Center, attest to the competitive attraction of the Jupiter area.

• Did subsidies create jobs in Florida’s biotech region at a reasonable cost?
  Failed outcome = D
  The startup subsidies of $910 million should be prorated over a 10-year prospective life for Scripps Florida and a 7-year life for Sanford Burnham. Over 10 years, Scripps Florida should create 5,450 job-years of employment. Over 7 years, Sanford Burnham at most created 1,820 job-years. The combined total is about 7,300 job-years. The taxpayer cost works out to about $125,000 per job year, substantially more than the annual wage at Scripps Florida, about $70,000 for staff scientists. On the other hand, Scripps Florida drew federal and foundation money and attracted other biotech firms to the area. As explained in chapter 1, jobs created in other firms and income multiplier benefits are not counted in our analysis.

• Did Florida’s biotech hub advance the technological frontier of life sciences?
  Successful outcome = A
  Scripps Florida made advances in drugs for arthritis, lupus, hairy cell leukemia, lung cancer, muscular dystrophy, and other ailments.104

ADVANCED TECHNOLOGY VEHICLES MANUFACTURING LOAN PROGRAM (ATVM)

In fall 2008, when the Great Financial Crisis was raging, at the request of President George W. Bush, Congress enacted the Advanced Technology Vehicles Manufacturing Loan Program (ATVM), administered by the Department of Energy. As the name suggests, the program was designed to harness advanced technology for energy-efficient automobiles and components by providing low-cost debt capital. Advanced technology vehicles are required to meet Clean Air Act Tier 2 emissions and particulate standards, and to achieve 25 percent higher fuel economy than the average fuel economy for vehicles in 2005 (Canis and Yacobucci 2015).

ATVM had direct loan authority of $25 billion, supported by appropriated credit subsidies (in the event of loan losses) of $7.5 billion (30 percent of loan authority), and the interest rate was a modest 4 percent. DOE soon received 108 loan requests, of which only four were granted in 2009, totaling $8.5 billion:

• Ford Motor Company, $5.9 billion for upgrading factories
• Nissan North America, $1.6 billion for advanced electric vehicles and batteries

• Tesla Motors, $465 million for a new electric sedan
• Fisker Automotive, $529 million for plug-in hybrid autos

No further loans were granted, and in February 2020 the Trump administration attempted to cancel the ATVM Loan Program.\textsuperscript{105} The four loans granted in 2009 assisted one spectacular success, Tesla Motors, and suffered one failure, Fisker Automotive. Tesla repaid its loan plus interest in 2013; Nissan repaid its loan plus interest in 2017; Ford plans to complete its repayments in 2023. Because of Fisker's corporate failures, DOE funded only $192 million of the Fisker loan. When Fisker went into bankruptcy in 2013, DOE recovered $53 million, incurring a loss of $139 million. Overall, the taxpayer cost of ATVM was modest relative to the magnitude of loans extended (about 1.7 percent).

Calculating jobs created by ATVM is more difficult. Tesla was a struggling concern in 2009 when the DOE loan of $465 million was granted, and employment was 650. But Tesla's fortunes soon improved, mainly owing to the leadership of Elon Musk; in 2013, when Tesla repaid the loan, employment was 5,859.\textsuperscript{106} Generously attributing all the employment growth to the DOE loan, perhaps 13,000 job-years were created. Fisker had a payroll of 2,800 in 2009 when it secured the DOE loan. Assuming the payroll remained constant until 2013 when Fisker shut down, another 2,800 job-years can be attributed to the ATVM. Despite the Great Financial Crisis of 2008-09, it seems difficult to attribute job gains to either the Ford or Nissan loans, since both companies could have accessed the private capital markets. All told, a reasonable number of job-years created by ATVM, counting only Tesla and Fisker, might be about 15,800.

Clearly Tesla has advanced technology with its latest electric autos, and some credit owes to the DOE loan. It’s less clear whether Ford or Nissan made significant breakthroughs based on the ATVM credits, though both firms are pouring substantial effort into electric and hybrid cars. A recent report suggests that the ATVM program helped to expand facilities for manufacturing advanced technology vehicle battery cells and packs in the United States (White House 2021).

**Summary Evaluation and Brief Explanations**

- **Are US electric vehicles internationally competitive?** Successful outcome = A
- Although Fisker failed, Tesla became the leading US electric vehicle producer. US exports of electric vehicles doubled from $3 billion in 2017 to $6 billion in 2020.\textsuperscript{107} But Tesla commenced major production in China and the US share of global electric vehicle exports declined from 38 percent to 16 percent between 2017 and 2020, ranking third after Belgium and Germany.

- **Did the ATVM subsidy create jobs at a reasonable cost?**
  - Successful outcome = B
  - Tesla and Fisker received loans of about $994 million, and federal loan losses were only $139 million. The ATVM program may have created 15,800


\textsuperscript{106} I. Wagner, “Number of Tesla employees from July 2010 to December 2020,” Statistica, March 9, 2021.

\textsuperscript{107} Trade data are based on Harmonized Tariff Schedule code 870380.
job-years in Tesla and Fisker, so the taxpayer cost per job-year may have been as low as $8,800. Average annual earnings in the automobile industry were about $59,520 in 2013. But the cost per job-year calculations entails some conjecture.

- **Did the ATVM subsidy advance the technological frontier?**
  
  **Successful outcome = A**
  
  Giving only a fraction of the credit for Tesla’s electric vehicle success to the ATVM loan, this was a technological winner.

**OPERATION WARP SPEED**

Responding to the COVID-19 pandemic, President Trump announced Operation Warp Speed on May 15, 2020. The core idea was a public-private partnership to discover and manufacture effective vaccines. This program, which additionally secured supply chains for vaccine production, has merits for the rest of the world to adopt.

The US government committed to large purchases in advance and matched suppliers with vaccine sponsors so that purchase orders would be fulfilled. Also, by subsidizing input production capacity such as capital equipment and raw materials, as well as syringes, vials, and other ancillary supplies, the US government strived to minimize potential input bottlenecks during vaccine production. Warp Speed was initially funded with $10 billion drawn from the Coronavirus Aid, Relief, and Economic Security (CARES) Act, which was passed on March 27, 2020, and assigned responsibilities to multiple federal agencies. In October 2020 funding was raised to $18 billion. The initial goal was to deliver 300 million doses of vaccine with at least 50 percent effectiveness by January 2021.

The two main financial channels from Warp Speed to pharmaceutical firms were R&D grants and vaccine purchase agreements. Table 4.2 summarizes the recipients and the amount of support they received.

Operation Warp Speed was remarkably successful by all metrics. Historically, development times for new vaccines are two years or more. By December 2020, four new vaccines were authorized for use by the US Food and Drug Administration (FDA) or the UK Ministry of Health. In January 2021 President Biden announced a target of 100 million vaccinations in his first 100 days in office. This rate was soon exceeded; in May 2021, he announced a new target of 70 percent of Americans vaccinated by July 4, 2021. As of July 21, the share who had received at least one dose of vaccines exceeded 55 percent of the US population.

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Table 4.2
Operation Warp Speed vaccine contracts

<table>
<thead>
<tr>
<th>Company</th>
<th>Quantity in contract (million doses)</th>
<th>Funding (billions of dollars)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pfizer-BioNTech</td>
<td>100</td>
<td>5.97</td>
</tr>
<tr>
<td>Johnson &amp; Johnson</td>
<td>100</td>
<td>1.46</td>
</tr>
<tr>
<td>Moderna</td>
<td>200</td>
<td>5.85</td>
</tr>
<tr>
<td>AstraZeneca-Oxford</td>
<td>300</td>
<td>1.20</td>
</tr>
<tr>
<td>Novavax</td>
<td>100</td>
<td>1.60</td>
</tr>
<tr>
<td>Sanofi-GlaxoSmithKline</td>
<td>100</td>
<td>2.07</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>900</strong></td>
<td><strong>18.15</strong></td>
</tr>
</tbody>
</table>


Chad Bown and Thomas Bollyky (2021) provide a detailed account of US vaccine success. An important contributing feature was priority access to key ingredients in the vaccine supply chain (through the Defense Production Act) and international cooperation in technology and production.

The Pfizer-BioNTech and Moderna vaccines used a novel mRNA approach that seems adaptable to emerging variants of the SARS-Cov-2 virus (the technical name for the COVID-19 virus). Johnson & Johnson and AstraZeneca used the more traditional adenovirus viral vector approach. Early in 2021, these last two vaccines were linked to very rare blood clot disorders and their use was limited. Nevertheless, with effectiveness rates of 80 percent and higher, vaccines have been given to hundreds of millions of Americans and Europeans, sharply reducing new cases and death rates, and enabling relaxation of lockdown measures. Owing to this success, prospects seemed bright for strong economic recovery in the second half of 2021, especially in the United States. Emergence of the Delta variant, and the reluctance of many Americans to take a vaccine, have somewhat dampened the pace of recovery.

Joseph Gagnon, Steven Kamin, and John Kearns (2021) estimated that a faster pace of vaccinations (by three or four months) might have saved an additional 35,000 American lives and boosted GDP by $64 billion. That calculation suggests that, if Operation Warp Speed accelerated vaccine delivery by just six months, the GDP gains were at least $128 billion, exceeding the cost by far.

Nations in South Asia, Africa, and Latin America are clamoring for access to the four proven vaccines. China and Russia have filled some of the demand with their adenovirus vaccines, but Chinese vaccine effectiveness rates may not exceed 50 percent.\textsuperscript{111} Going forward in 2021 and 2022, supplying effective

vaccines to billions of people will be a major challenge. At the G7 summit in June 2021, President Biden announced that the United States would donate 500 million vaccine doses to developing economies, and other G7 countries announced an additional 500 million doses, bringing prospective total donations to 1 billion in 2021.

Summary Evaluation and Brief Explanations

• Are the US vaccines internationally competitive? Successful outcome = A
  Worldwide demand for the US vaccines attests to their competitive strength. However, critical supply chains were cross-border, and between the United States and United Kingdom there was considerable cross-dependency of technology. Accordingly, US vaccines contained major international components.

• Did the industry subsidy create jobs at a reasonable cost? Successful outcome = A
  No calculation is necessary. Considering that COVID-19 caused 2,023 cumulative deaths per million in the United States as of mid-September 2021, the vaccines clearly saved millions of job-years as Americans returned to work. The US unemployment rate dropped to 5.2 percent in August 2021.

• Did the industrial subsidy advance the technological frontier? Successful outcome = A
  The mRNA vaccine represents a stunning technological breakthrough. It teaches cells how to make a protein that triggers an immune response in the body, which is a new approach to vaccines. And the formula for making mRNA vaccine is quite difficult and technical.

NORTH CAROLINA RESEARCH TRIANGLE PARK

The highly successful Research Triangle Park (RTP), often claimed as an exemplar of industrial policy, has little in common with the other initiatives examined in this chapter. The “triangle” describes the proximity of North Carolina State University (State) in Raleigh, Duke University (Duke) in Durham, and the University of North Carolina (UNC) in Chapel Hill, all of which long preexisted the RTP.

In 1959 a group of prominent North Carolina businessmen led by Karl Robbins, a textile millionaire, reasoned that tobacco, textiles, and furniture were not the state’s economic future. At the time North Carolina ranked 47th in state per capita income, and most university graduates headed north with their degrees. Robbins gave the state 4,000 pinewood acres situated between the three universities. The Research Triangle Foundation, a nonprofit corporation, raised about $1.5 million in private money to purchase an additional 3,000 acres, launching the Park with 7,000 acres. Good highways traversed the area.

Governor Luther Hodges warmly endorsed the initiative, but state support consisted of just three central features, two of which preexisted the RTP. First, and most important, was ongoing generous funding of the two state universities, State and UNC; table 4.3 illustrates the rapid expansion of UNC’s budget (Duke was already well endowed and could grow with alumni gifts). Second, North Carolina was a right-to-work state (since 1947), meaning that union membership could not be required as a condition of employment. Third, and novel, was
incorporation of the RTP, prohibiting annexation by municipalities in the neighboring counties of Wake, Durham, and Orange, and capping the property tax rate at 10 cents per $100 of valuation (a remarkably low 0.1 percent tax rate).

Table 4.3
Operating revenues of the University of North Carolina, 1990–2020 (millions of dollars)

<table>
<thead>
<tr>
<th>Source</th>
<th>1990</th>
<th>2000</th>
<th>2010</th>
<th>2020</th>
</tr>
</thead>
<tbody>
<tr>
<td>Student tuition and fees, net</td>
<td>47</td>
<td>122</td>
<td>249</td>
<td>400</td>
</tr>
<tr>
<td>Patient services, net</td>
<td></td>
<td>243</td>
<td>491</td>
<td></td>
</tr>
<tr>
<td>Federal grants and contracts</td>
<td>133</td>
<td>321</td>
<td>530</td>
<td>722</td>
</tr>
<tr>
<td>State support</td>
<td>253</td>
<td>383</td>
<td>547</td>
<td>550</td>
</tr>
<tr>
<td>Nongovernment grants and contracts</td>
<td>50</td>
<td>57</td>
<td>121</td>
<td>150</td>
</tr>
<tr>
<td>Sales and services, net</td>
<td>152</td>
<td>323</td>
<td>354</td>
<td>435</td>
</tr>
<tr>
<td>Other revenues</td>
<td>22</td>
<td>40</td>
<td>7</td>
<td>13</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>656</td>
<td>1,246</td>
<td>2,052</td>
<td>2,762</td>
</tr>
</tbody>
</table>

Note: State support includes state appropriation, state grants and contracts. So the total may be different from the original source. Other revenues include investment and endowment income, interest earnings, and gifts and bequests.


In the 1960s the North Carolina corporate income tax rate was 6.9 percent, already high by state standards; in 1997 it was raised to 7.5 percent. Tax reform swept the state and the corporate rate for 2021 was slashed to 2.5 percent, the lowest among the 44 states that impose a corporate tax. Thus, favorable corporate taxes were not a drawing card in the early RTP period but became more important in the 2010s. Since 2014, 6.9 percent corporate income tax rate in North Carolina started to drop by 1 percent annually and reached 2.5 percent in 2021.112

Once the Park was established in 1959, the North Carolina businessmen went north to attract major corporations. The first big catch was IBM, followed by Burroughs Wellcome, Glaxo (now GlaxoSmithKline), Northern Telecom, and many others. Figure 4.7 portrays the growth of RTP employment as more firms took advantage of its amenities—park layout, good schools, pleasant housing, and skilled workforce. Per capita income of the RTP area grew rapidly, especially after 1980 (Weddle 2009).

RTP’s success in attracting firms was not much different from organic growth near universities elsewhere: a cluster of Silicon Valley firms around Stanford, the diverse cluster around MIT and Harvard, the tech cluster around the University of Texas in Austin, and parallel experience in other states. The main difference is that the Research Triangle brand gave North Carolina’s success an industrial policy flavor absent elsewhere, although research in RTP was largely conducted and paid for by private firms, in some cases assisted by federal grants, without much state money (the same was true in university settings elsewhere).

North Carolina’s contribution was not targeted assistance to specific firms but rather broad probusiness policies: university funding, right to work, and capped property taxes. According to US Census Bureau data, North Carolina operating expenditures in higher education increased from $2.3 billion in 1993 to $8.5 billion in 2019. In Alabama, expenditure in higher education also grew from $1.6 billion in 1993 to $5.7 billion in 2019. The budget in higher education in Texas jumped from $5 billion to $26.7 billion in the same period. Figure 4.8 shows a growing trend of STEM majored students at the University of North Carolina, guaranteeing that tech firms in RTP can hire high-quality workers.

The Park’s property owners pay property taxes only to the county government, not to the city government. Thus, by decreasing the overall tax burden facing RTP landowners, the law makes RTP a more attractive place for companies to conduct their R&D.
Summary Evaluation and Brief Explanations

- **Is the Research Triangle Park nationally and internationally competitive?**
  
  **Successful outcome = A**
  
  RTP exemplifies industrial clustering around universities, promoting employment and per capita income growth. RTP enabled companies to establish relationships with universities in the region, giving firms access to a large pool of university graduates.

- **Did state subsidies to the RTP create jobs at a reasonable cost?**
  
  **Successful outcome = A**
  
  State support mainly takes the form of operating expenditures for higher education, some $8.5 billion statewide in 2018. State support for the University of North Carolina and North Carolina State University was $550 million and $523 million in 2020, respectively (table 4.3 shows the UNC figures). Meanwhile, according to the Research Triangle Foundation, the three RTP universities receive $3 billion research funding annually from federal and private sources—an amount that substantially exceeds state support.\(^{114}\) The state cost per job created in RTP is about $8,250, dividing the state support to UNC and NC State in 2020 ($1,073 million) by the employment level in RTP in the same year (130,000 employees from RTRP (2020)). The average earning of tech workers in North Carolina is about $80,800 per year.\(^{115}\)

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• Did RTP advance the technological frontier? Successful outcome = A
In the Research Triangle region, there are about 7,000 companies and 130,000 employees in sectors such as advanced manufacturing, technology, clean technology, life science, and agricultural technology. Between 2015 and 2019 North Carolina created more than 170 startups drawing $1.7 billion in venture capital.\textsuperscript{116} The data speak to advances across multiple technological frontiers.

SUMMING UP
Support of public and private R&D has been easily the most successful mode of industrial policy. One reason is US strength, backed by major universities, in research endeavors. Another reason is the US tradition of giving scope and support for competing scientists to pursue the same objective. A third reason, for public R&D, is the practice of allowing private firms to commercialize findings, typically with modest or no royalty payments to the government.

The case for supporting public and private R&D is strengthened by well-known externalities: rarely do discoverers capture 100 percent of the financial benefits from their innovations, even with patent protection. Typically, a large share of benefits flows to firms that did not incur the R&D expense, or to society at large through new products or lower prices.

Of course R&D has many failures, but the long-term record is that successes more than pay for failures. The US rate of return on public R&D outlays has been estimated as high as 67 percent (Elk et al. 2019).

REFERENCES


5 Summary of Findings and Policy Recommendations

INTRODUCTION

This concluding chapter summarizes the impact of US industrial policy episodes over the past 50 years and offers policy recommendations. Recommendations are timely, now that Congress and the administration have rediscovered their appetite for industrial ventures—spurred by competition with China. Lawmakers are drafting legislation to expand domestic production of critical technologies such as semiconductors, batteries, and solar components. Our findings suggest moderation and caution.

Over the past half-century, federal and state governments invoked multiple arguments to justify industrial policies:

- to rejuvenate aging industries (exemplified by steel, textiles, and apparel);
- to compensate for externalities (notably in the energy sphere);
- to promote growth and jobs (as in the automotive sector); and
- to advance the technological frontier, especially in the interest of national security.

This study examined 18 US industrial policy episodes implemented between 1970 and 2020, dividing them into three broad categories: cases where trade measures blocked the US market or opened foreign markets, cases where federal or state subsidies were targeted to specific firms, and cases where public and private R&D was funded to advance technology. The outcome of each episode was scored by grading three criteria: the effect on US competitiveness in global markets (or in some cases the national market), whether the annual cost per job saved or created in the sector was reasonable (i.e., no more than the prevailing average wage), and whether support advanced the technological frontier. For each criterion, a score of D represents our judgment of failure; a score of A represents our judgment of success; and a score of B or C represents an intermediate outcome. Table 5.1 summarizes the scores of each episode according to the three dimensions. Some are partly or entirely successful while others are complete failures.

### Table 5.1
**Scorecard for US industrial policy, 1970–2020**

<table>
<thead>
<tr>
<th>Measure/firm/industry/entity</th>
<th>Did the industry become competitive in international or national markets?</th>
<th>Were jobs saved* or created in the industry at a reasonable cost?</th>
<th>Was the technological frontier advanced by government assistance?</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Trade measures</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Steel*</td>
<td>D</td>
<td>D</td>
<td>D</td>
</tr>
<tr>
<td>Textiles and apparel*</td>
<td>D</td>
<td>D</td>
<td>C</td>
</tr>
<tr>
<td>Automobiles</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Assembly*</td>
<td>A</td>
<td>A</td>
<td>A</td>
</tr>
<tr>
<td>Parts*</td>
<td>B</td>
<td>C</td>
<td>A</td>
</tr>
<tr>
<td>Semiconductors</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Antidumping phase*</td>
<td>D</td>
<td>D</td>
<td>C</td>
</tr>
<tr>
<td>Foreign market opening phase*</td>
<td>B</td>
<td>A</td>
<td>A</td>
</tr>
<tr>
<td>Solar panels</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tax credit phase</td>
<td>D</td>
<td>A</td>
<td>A</td>
</tr>
<tr>
<td>Trade protection phase*</td>
<td>D</td>
<td>B</td>
<td>D</td>
</tr>
<tr>
<td><strong>Subsidies to targeted firms</strong></td>
<td><strong>2.2</strong></td>
<td><strong>2.5</strong></td>
<td><strong>1.8</strong></td>
</tr>
<tr>
<td>Synthetic Fuels Corporation</td>
<td>D</td>
<td>D</td>
<td>D</td>
</tr>
<tr>
<td>Solyndra Corporation</td>
<td>D</td>
<td>D</td>
<td>D</td>
</tr>
<tr>
<td>Crescent Dunes</td>
<td>D</td>
<td>D</td>
<td>D</td>
</tr>
<tr>
<td>Mercedes-Benz in Alabama</td>
<td>A</td>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td>Chrysler bailout in 1980*</td>
<td>A</td>
<td>A</td>
<td>A</td>
</tr>
<tr>
<td>Foxconn in Wisconsin</td>
<td>C</td>
<td>B</td>
<td>D</td>
</tr>
<tr>
<td><strong>Public and private research and development</strong></td>
<td><strong>3.6</strong></td>
<td><strong>3.4</strong></td>
<td><strong>4.1</strong></td>
</tr>
<tr>
<td>Defense Advanced Research Projects Agency (DARPA)</td>
<td>A+</td>
<td>A+</td>
<td>A+</td>
</tr>
<tr>
<td>Renewable energy</td>
<td>D</td>
<td>A</td>
<td>A</td>
</tr>
<tr>
<td>Sematech</td>
<td>C</td>
<td>B</td>
<td>A</td>
</tr>
<tr>
<td>Florida Biotech Region</td>
<td>A</td>
<td>D</td>
<td>A</td>
</tr>
<tr>
<td>Advanced Technology Vehicles Manufacturing Loan Program</td>
<td>A</td>
<td>B</td>
<td>A</td>
</tr>
<tr>
<td>Operation Warp Speed</td>
<td>A</td>
<td>A</td>
<td>A</td>
</tr>
<tr>
<td>North Carolina Research Triangle Park</td>
<td>A</td>
<td>A</td>
<td>A</td>
</tr>
</tbody>
</table>

Scores are A+ = 4.5; A = 4; B = 3; C = 2; D = 1.
* = cases that saved existing US jobs, as opposed to creating new jobs.
INDUSTRIAL POLICY THROUGH TRADE MEASURES

The federal government commonly uses trade measures to carry out industrial policy, partly because such measures are off-budget. Costs, which can be substantial, are usually disguised in higher prices paid by household and business users. Chapter 2 examined five cases that involved trade measures to support US industries making steel, textiles and apparel, automobiles, semiconductors, and solar panels.

The classic test for evaluating competitive success is simple: Could the industry prosper without continued import protection and did it achieve significant export sales? By this test, only automobile assembly had a successful outcome from trade measures. Voluntary restraint agreements accelerated the migration of Japanese auto producers to American soil, bringing with them superior designs and better production methods. Qualified success (a score of B) was achieved for the auto parts industry, owing to supply chain connections to Japanese auto assembly firms. US semiconductors also achieved success in exports for a few years in the 1980s and 1990s as the Japanese market was opened to them.

Other trade cases, however, failed the classic competitive test. Protection for steel, textiles and apparel, semiconductors (the antidumping duty phase), and solar panels did not create US industries that could meet foreign competition. The steel industry, for example, continues to demand import protection, and its exports remained stuck at about 8 percent of domestic production between 1970 and 2019, mainly in sales to related firms in Mexico and Canada. We conclude that import protection rarely leads to competitive success. In selected cases, opening foreign markets may enhance the competitive position of US firms.

As a second criterion, we examined whether jobs were saved or created in the targeted industry at a reasonable cost, generously defined as the cost to taxpayers or consumers not exceeding the prevailing annual wage. This criterion does not consider jobs lost in downstream industries. In some instances, however, jobs lost in the wider economy substantially outnumber jobs saved in the targeted industry. Among the industrial policy cases entailing trade measures, several meet our criterion: automobile assembly, opening the Japanese semiconductor market, and tax credits and protection for solar panels. However, consumer costs per job saved were spectacularly high for steel, textiles and apparel, and semiconductors under antidumping duties. On balance, and considering jobs lost in downstream industries, trade protection is not the way to create jobs in the American economy. Indeed, as President Trump’s massive protection against manufactured imports from China once again proved, trade protection was a significant job killer.118

For our third criterion we asked whether industrial policy through trade measures advanced the technological frontier. Success was registered in three instances: for automobile assembly and parts, because voluntary restraints accelerated the entry of Japanese firms as American producers; for semiconductors from opening the Japanese market; and for solar panels owing to massive demand spurred by tax credits. We conclude that trade measures can

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succeed by luring world-class foreign producers to locate in the United States and by significantly boosting demand for products on the cusp of technological innovation. These conditions seldom characterize aging industries that are often favored by import protection.

**INDUSTRIAL POLICY BY SUBSIDIZING SELECTED FIRMS**

Chapter 3 examined six instances where government subsidized specific firms rather than whole industries (the object of industrial policy through trade measures). In three of the cases, the federal government supported specialized energy firms mandated to advance frontier technology: the Synthetic Fuels Corporation, Solyndra Corporation, and Crescent Dunes. All three were spectacular failures, whether judged by competitive outcomes, cost per job created, or technology achievements. It is possible that our sample overlooks successful government-sponsored innovators (commercial equivalents of the Manhattan Project). But a more likely explanation is that frontier technology is, by definition, high risk. Focusing public money on one or two firms may foreclose alternative innovative solutions that are advocated by different scientific or business leaders that may have been more effective. In any event, despite public support, the three energy ventures failed to meet their contractual production levels and were eventually shut down with no contribution to energy technology.

Three other, very different episodes, with distinct outcomes, were Alabama’s support for the Mercedes-Benz plant, the federal bailout of Chrysler, and Wisconsin’s support for the Foxconn plant. The Mercedes and Foxconn episodes typify hundreds of similar efforts by state governments to lure established firms to locate new facilities within state borders. Seldom is the goal of state incentives to advance the technological frontier. Similarly, competition in international markets is secondary and rarely tracked. Instead, the core objective is jobs, jobs, jobs—in successful firms. A recent example of this brand of industrial policy was Virginia’s success in luring Amazon to locate a major facility in the DC suburbs. The New York offer, while generous ($3 billion), faced intense political opposition, unlike the smaller Virginia offer ($800 million). Perhaps as well Amazon saw value in the proximity of the Virginia location to Congress and federal agencies.

In the Mercedes-Benz episode, the German automaker received generous state subsidies to build a plant in Alabama, and the subsidies were less per job-year than the average Mercedes wage. As side benefits, Mercedes became more competitive in the US luxury car market, and very likely imported advanced technology from Germany to Alabama.

But it is an open question whether state subsidies, of the kind exemplified by Mercedes or Foxconn, represent a better use of state funds than alternatives, such as STEM programs at a state university. Scholars have questioned the wisdom of competition between states to attract desirable firms. From a national perspective, it is hard to justify the wisdom of state-versus-state industrial competition, but the immediate high-profile payoff at a state level is hard to deny.
INDUSTRIAL POLICY THROUGH PUBLIC AND PRIVATE SUPPORT FOR R&D

Some industrial policies prioritize research and development (R&D) to advance the technology frontier and, as secondary outcomes, create new industries and make competitive goods and services. Chapter 4 reviewed seven such industrial policy episodes: the Defense Advanced Research Projects Agency (DARPA), renewable energy programs, Sematech, Florida’s biotech center, the Advanced Technology Vehicles Manufacturing (ATVM) Loan Program, Operation Warp Speed, and North Carolina’s Research Triangle Park (RTP). Five of these were federal initiatives.

Within this group, and indeed in the entire study, the outstanding success is DARPA. DARPA projects, at comparatively modest cost, not only maintained US military technology at the world frontier but also spawned numerous spillovers to high-tech US firms in digital and other spheres. The payoff in terms of all three criteria has been enormous: internationally competitive firms, numerous new jobs, and frontier commercial technology.

Other federal departments have attempted to emulate DARPA’s success, but with far smaller budgets and less spectacular achievements. Pierre Azoulay and colleagues (2019) summarize elements of the “DARPA model” and their analysis suggests significant, but not insuperable, challenges to replicating the mode of operation in other public or private settings, such as ARPA-E in the Department of Energy or the Howard Hughes Medical Institute. In his address to Congress on April 28, 2021, President Biden commended the DARPA model, a hopeful sign for the coming generation of industrial policy initiatives.119

Among the other R&D episodes, Sematech was only moderately successful, for two reasons. Leading US semiconductor firms decided, after a few years, that in-house R&D was a better proposition than R&D shared through the Sematech consortium. Equally important, these firms decided to focus on advanced design in their US R&D centers; they shifted production offshore to take advantage of lower wages and foreign industrial subsidies. US firms thrived, but US production of semiconductors not so much.

Federal renewable energy programs did not create solar panels or wind turbines that could compete in world markets, but they did create jobs at reasonable cost and advance renewable energy technology. The ATVM program, launched by President George W. Bush, nourished Tesla in its early years, a noteworthy success in terms of US production, jobs, and technology. Operation Warp Speed, President Trump’s industrial policy vehicle for rapid production of COVID-19 vaccines, must be included in the roster of R&D successes. Several pharmaceutical firms were engaged through incentive contracts to conduct vaccine R&D and produce millions of vials. Not all pharma companies succeeded but three did in record time.

Turning to state ventures, Florida’s biotech center did not generate jobs at a reasonable cost, according to our threshold of taxpayer outlay per job-year, but it did foster cutting-edge technology by world-class firms. Finally, Research Triangle Park succeeded on all criteria, with very modest public support.

COMPETING WITH CHINA

China’s energetic support of high tech, symbolized by the “Made in China 2025” plan, triggered alarms in Washington. Of greater concern, Beijing’s latest five-year plan, released in 2021, sets out self-reliance goals for high-tech sectors including artificial intelligence, quantum information, and semiconductors. Total public R&D (basic plus applied) is slated to grow by more than 7 percent annually over the five years (not much faster than recent experience), with an increase of central government spending on basic research of 10.6 percent in 2021.

Barry Naughton (2021) documents that, after 1978 (when Deng Xiaoping came into power), China’s industrial policy evolved from inconsistent planning to broad technoindustrial goals and then focused on sector-specific industrial policies (the Innovation-Driven Development Strategy). Government Industrial Guidance Funds—established in 2014 to help private firms scale up rapidly to run large-scale projects—financed major initiatives, with cumulated support between 2014 and 2020 of about $1.6 trillion (Naughton 2021). High-tech industries including industrial robots, autonomous vehicles (commercial and military), semiconductors, and artificial intelligence account for 50 percent of the total allocation of Industrial Guidance Funds. Based on this record, Naughton characterizes China as a government-steered market economy.

President Trump launched a trade policy response to the Chinese challenge, erecting a tariff wall on imports, blacklisting Chinese firms (notably Huawei), and restricting commerce in high-tech goods and technology. Adding to this agenda, in February 2021 President Biden issued an executive order calling for a 100-day review of supply chain constraints in four sectors with exposure to China: pharmaceuticals, semiconductors, high-capacity batteries, and strategic materials (e.g., rare earths). To ensure resilient supply chains in those and other sectors, a new tranche of US industrial policy is under development. Supply chain resiliency was not an objective of pre-2020 cases examined in this study, but has become a future target, in response to both China’s rise and the COVID-19 pandemic. The central recommendations of US supply chain review are to rebuild domestic production and innovation capabilities of key products (such as those in the four sectors just mentioned) and to strengthen government involvement in purchasing and investing in such products via subsidies, tax incentives, and loan programs (White House 2021).

Beyond supply chains, technological rivalry will drive the US response to China. On June 8, 2021, the Senate passed the American Innovation and Competition Act, which provides (in the overall budget of $250 billion) some $52 billion for semiconductor R&D and manufacturing, to strengthen the sector’s capacity to compete against China. With the Soviet Union, it was an arms race; with China, it’s a technology race.

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120 Brett Fortnam, “China’s five-year plan sets goals for seven high-tech sectors, R&D spending,” Inside US Trade, March 5, 2021.
EAST ASIAN INDUSTRIAL POLICY

The World Bank’s acclaimed volume, East Asian Miracle: Economic Growth and Public Policy (Birdsall et al. 1993), while acknowledging industrial policies, emphasized sound macroeconomic policies (later labeled the “Washington Consensus”), together with superior education and land reform, as drivers of remarkable growth in Hong Kong, Japan, South Korea, Singapore, and Taiwan. A decade earlier, Chalmers Johnson (1982) had published MITI and the Japanese Miracle: The Growth of Industrial Policy, 1925-1975, giving outsized credit for Japan’s spectacular postwar economic growth to government support for specific firms and industries. These two volumes set the stage for prolonged debate, still underway, on the role of industrial policy in East Asian economic prosperity. Numerous academic articles and books have dissected contributing factors. This brief section merely skims the surface of a substantial literature.

Three key facts, summarized in table 5.2, set the stage. Between 1950 and 1990 in the East Asian stars, real exports generally grew, real GDP soared, and per capita income dramatically closed the gap with US levels. Industrial policy protagonists saw cause and effect between government intervention—trade protection, easy credit, assorted subsidies, cartels—and these indisputable outcomes. To be sure, Hong Kong practiced laissez-faire economics under British rule, and Singapore’s principal “intervention” was making itself an attractive location for foreign multinationals. Japan, South Korea, and Taiwan were the clear exemplars of industrial policy.

In 2003 Marcus Noland and Howard Pack authored Industrial Policy in an Era of Globalization: Lessons from Asia, first summarizing the literature, and then contrasting macro forces with industrial policy in the postwar recovery and subsequent growth of the three exemplars. Their analysis relied heavily on quantitative measures rather than accounts of targeted government policies or the rise of specific firms such as Mitsubishi, Toyota, POSCO, Samsung, China Steel, or Taiwan Semiconductor Manufacturing Corporation (TSMC).

Analyzing sector growth, value added, capital accumulation, and total factor productivity in Japan and Korea, Noland and Pack (2003) found little or no correlation between the quantitative outcomes and various industrial policy indicators such as tariffs, tax rates, and government loans (e.g., tables 2.5 and 2.8). On the other hand, they found that the growth of physical capital per worker, education per worker, and total factor productivity fully explained the remarkable growth of output per worker in South Korea and Taiwan (table 4.3). These contributing factors were much weaker in Latin America and South Asia, two regions that heavily favored industrial policy and fared poorly during the era of the East Asian miracle. The differing fates of East Asia and the other two regions owe to the political and economic stability and superior macroeconomic and education policies of East Asia: few coups, relatively low inflation, high savings rates, modest budget deficits, and high secondary and tertiary education rates. The authors conclude (p. 93) that, “on balance, the weight of the evidence derived from both econometric and input-output studies of these economies... indicates that industrial policy made a minor contribution to growth in Asia.”
Table 5.2
Stylized economic indicators in East Asia: Hong Kong, Japan, Singapore, South Korea, and Taiwan, various years

<table>
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<tr>
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<tbody>
<tr>
<td>a. Ratio of total trade to GDP, 1970–88</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hong Kong</td>
<td>1.50</td>
<td>1.52</td>
<td>1.78</td>
<td>2.82</td>
</tr>
<tr>
<td>Japan</td>
<td>0.19</td>
<td>0.25</td>
<td>0.23</td>
<td>0.11</td>
</tr>
<tr>
<td>Singapore</td>
<td>2.12</td>
<td>3.70</td>
<td>2.77</td>
<td>3.47</td>
</tr>
<tr>
<td>South Korea</td>
<td>0.32</td>
<td>0.63</td>
<td>0.66</td>
<td>0.66</td>
</tr>
<tr>
<td>Taiwan</td>
<td>0.53</td>
<td>0.95</td>
<td>0.82</td>
<td>0.90</td>
</tr>
<tr>
<td>b. Real GDP in billions of 2017 US dollars, 1960–90</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hong Kong</td>
<td>13.2</td>
<td>29.8</td>
<td>70.6</td>
<td>135.3</td>
</tr>
<tr>
<td>Japan</td>
<td>609.6</td>
<td>1,601.4</td>
<td>2,478.1</td>
<td>3,860.4</td>
</tr>
<tr>
<td>Singapore</td>
<td>8.5</td>
<td>20.3</td>
<td>471</td>
<td>99.3</td>
</tr>
<tr>
<td>South Korea</td>
<td>40.6</td>
<td>85.5</td>
<td>207.4</td>
<td>538.6</td>
</tr>
<tr>
<td>Taiwan</td>
<td>19.3</td>
<td>51.2</td>
<td>138.2</td>
<td>304.1</td>
</tr>
<tr>
<td>c. Real GDP per capita in 2010 US dollars, 1960–90</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hong Kong</td>
<td>n.a.</td>
<td>5,796</td>
<td>10,727</td>
<td>18,251</td>
</tr>
<tr>
<td>Japan</td>
<td>8,542</td>
<td>18,870</td>
<td>25,849</td>
<td>38,093</td>
</tr>
<tr>
<td>Singapore</td>
<td>3,503</td>
<td>6,787</td>
<td>13,534</td>
<td>22,572</td>
</tr>
<tr>
<td>South Korea</td>
<td>932</td>
<td>1,793</td>
<td>3,679</td>
<td>8,496</td>
</tr>
<tr>
<td>Taiwan</td>
<td>1,805</td>
<td>3,510</td>
<td>7,808</td>
<td>14,995</td>
</tr>
</tbody>
</table>

n.a. = not available

Sources: Birdsall et al. (1993, page 39) and Federal Reserve Bank of St. Louis.

Subsequent scholars returned to the Chalmers Johnson approach: focusing on particular industrial policy episodes and the success of individual Asian firms. For example, Nathan Lane (2021) rehabilitated the heavy and chemical industry episode of Korean industrial policy (1973–79), documenting its contribution to sectoral output and downstream benefits. Jostein Hauge (2020) advocated a “developmentalist framework” for giving proper credit to the contribution
of industrial policy to the success of South Korea and Taiwan between 1960 and 1990. On the other hand, Cheng Tun-jen (2001) emphasized the role of market reforms, advocated by US officials, in Taiwan’s postwar success. None of these articles overturned the findings of Noland and Pack (2003) that broad macroeconomic policies in all five countries made a far greater contribution to the East Asian miracle than industrial policy.

The relevant lesson for our report is straightforward. If extensive industrial policies made only a minor contribution to East Asia, far less extensive industrial policies—minuscule by comparison—cannot be expected to shape the economic destiny of the United States. That said, it is important that whatever public resources are allocated to targeted industrial policies be spent in the wisest possible manner.

POLICY OBSERVATIONS

A surge of industrial policy during the Biden administration seems inevitable. Brian Deese, director of the White House’s National Economic Council, has called for aggressive industrial support both to reduce supply chain vulnerability and to compete with China. In the wake of pandemic relief that has expended some $3 trillion of public funds to afflicted families and firms, public acceptance of “big government” runs high. Recognized scholars endorse the new mood, though with caveats. Of course, support for “big government” is not a prerequisite for industrial policy: witness episodes during the Reagan administration (no fan of big government) and multiple episodes in conservative southern states. Even so, in 2021 a deeply divided Congress has signaled strong bipartisan and bicameral support for legislation following Deese’s prescription: compete with China and ensure the security of supply chains, as summarized in table 5.3. Tolerance for major public spending provides a tail wind for industrial policy projects. Nevertheless, budget realities and private opposition will ultimately impose limits. Relative to GDP, the United States cannot match the scale of East Asian support during the 1960–90 era or the huge scale of Chinese subsidies today, nor will the US embrace the Chinese model of overarching government control.


124 For example, Ann E. Harrison, 2021 Paul Streeten Distinguished Lecture on Global Development Policy, reported by James Sundquist (March 8), “Don’t Be Afraid to Compete: The Role of Industrial Policy in Global Development,” Boston University Global Development Policy Center.
Table 5.3
Selected industrial policy–related projects in Congress

<table>
<thead>
<tr>
<th>Project</th>
<th>Incentives</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>S.1260 US Innovation and Competition Act</td>
<td>Endless Frontier Act: To promote US scientific and technological innovation R&amp;D in AI, robotics, wireless technologies, advanced space exploration, and others</td>
<td>Funding $200 billion</td>
</tr>
<tr>
<td></td>
<td>Passed in the Senate of 117th Congress</td>
<td></td>
</tr>
<tr>
<td>CHIPS Act: To boost semiconductor production and R&amp;D</td>
<td>Funding $52 billion</td>
<td></td>
</tr>
<tr>
<td>H.R.1599 Securing America’s Critical Minerals Supply Act</td>
<td>To secure the supply of critical energy resources, including critical minerals such as rare earths, and other material</td>
<td>Tax deduction for 200 percent of the extraction costs</td>
</tr>
<tr>
<td></td>
<td>Introduced in 116th Congress</td>
<td></td>
</tr>
<tr>
<td>S.3780 Help Onshore Manufacturing Efficiencies for Drugs and Devices Act</td>
<td>To support investment in advanced manufacturing for the domestic production of critical drugs, medical devices, and active pharmaceutical ingredients</td>
<td>Grants and forgivable loans</td>
</tr>
<tr>
<td></td>
<td>Introduced in 116th Congress</td>
<td></td>
</tr>
<tr>
<td>S.1366 Pharmaceutical Supply Chain Defense and Enhancement Act</td>
<td>To boost domestic drug and active ingredient manufacturing capacity</td>
<td>Funding $5 billion</td>
</tr>
<tr>
<td></td>
<td>Introduced in 117th Congress</td>
<td></td>
</tr>
</tbody>
</table>


With these considerations in mind, we offer four policy observations, distilled from this study of 18 industrial policy cases.

- **Industrial policy can save or create jobs, but often at high cost.** A major political selling point for industrial policy is to save or create jobs in a specific industry or location. In about half our sample, this was achieved at a taxpayer or consumer cost below the prevailing wage. But our calculations do not reflect the probable loss of downstream jobs, and in many instances the cost per job-year vastly exceeds the prevailing wage. Moreover, jobs created in one state often come at the expense of comparable jobs that might have been created in another state (Mercedes-Alabama; Foxconn-Wisconsin). At the national level, far better policies are available for creating jobs—for example, training programs and earned income tax credits.

- **Import protection seldom pays off.** A big exception: when actual or threatened barriers prompt a world-class firm to open in the United States. Toyota was an example in the 1980s; Taiwan Semiconductor Manufacturing Corporation (TSMC) is an example today. But in most cases, import protection does not create a competitive US industry and it imposes extreme costs on household and business users per job-year saved. Trade policy concentrated on opening markets abroad is a better bet.
• **Designating a single firm to advance technology yields inconsistent results.** Our study did not find single-firm triumphs that compare with the Manhattan Project. Perhaps they exist, but when government confines its support to a single firm to advance frontier technology, it forecloses alternative solutions that might be advocated by different scientists or business leaders. AVTM showed that it is much better to fund multiple firms at the outset. The highly successful model of Operation Warp Speed vividly demonstrated that competition is an American strength.

• **R&D industrial policy has the best track record by far.** Among the 18 cases, DARPA has the outstanding record. The DARPA model entails broad guidance to science and engineering experts who, without political interference, award grants to promising but high-risk R&D. When public R&D strikes gold, private firms step in to commercialize the findings. This model finds favor both with the Biden administration and the Congress. In fact, the Biden administration has proposed other projects—ARPA-Health and ARPA-Climate—fashioned after DARPA.125 Renewable energy R&D, Florida’s biotech region, and the North Carolina Research Triangle all attest to this industrial policy approach.

**REFERENCES**


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Appendix A

COMPUTABLE PARTIAL EQUILIBRIUM MODEL USED TO CALCULATE THE CONSUMER COST PER JOB-YEAR SAVED OR CREATED

This appendix summarizes the computable partial equilibrium model, largely drawn from Hufbauer and Elliott (1994).

The underlying domestic demand and supply functions are specified below:

\[ Q_d = aP_d^{E_{dd}}P_m^{E_{dm}} \]  \hspace{1cm} (1.1)  \hspace{1cm} \text{Primary Demand Function}

\[ Q_s = bP_d^{E_s} \]  \hspace{1cm} (1.2)  \hspace{1cm} \text{Primary Supply Function}

\[ Q_d \] is domestic demand and \( Q_s \) is domestic supply of the product in question. \( P_d \) represents the domestic price while \( P_m \) represents the landed import price (including the effect of tariff or nontariff barriers) in the domestic market. \( E_{dd} \) is the own price-elasticity of demand for the domestic commodity, which is defined as the percentage change in the quantity demanded for each 1 percent change in the price. Other elasticities are defined in a similar manner. \( E_{dm} \) is the cross-price elasticity of demand for the domestic commodity with respect to the price of the imported commodity. \( E_s \) is the own-price elasticity of the supply of the domestic good. Since the domestic commodity and the import are imperfect substitutes in this model, equilibrium in the domestic market requires that domestic demand equal domestic supply—in other words, \( Q_d \) equals \( Q_s \).

Assuming that the supply of the import is perfectly elastic, the supply and demand equations for the import market are:

\[ Q_m = cP_d^{E_{md}}P_m^{E_{mm}} \]  \hspace{1cm} (1.3)  \hspace{1cm} \text{Import Demand Function}

\[ P_m = P_m''(1 + t) \]  \hspace{1cm} (1.4)  \hspace{1cm} \text{Import Price Function}

\( Q_m \) is demand for the imported product and \( P_m \) is the landed import price. \( E_{md} \) is the cross-price elasticity of demand for the imported product with respect to the price of the domestic product, while \( E_{mm} \) is the own-price elasticity of demand for the imported product. \( P_m'' \) is the world price of the imported product. Tariff and/or nontariff barriers are denoted by \( t \); for example, an ad valorem tariff of 25 percent equates to a value of 0.25 for \( t \).

The model assumes that demand and supply relationships are linear in terms of their logarithms, enabling the parameters associated with the price terms to be interpreted as elasticities.

Transforming this system of demand and supply functions into a system of linear relationship by taking the logarithms to the base \( e \) (shown by \( \ln \)) of all the equations above gives:

\[ \ln Q_d = \ln a + E_{dd} \ln P_d + E_{dm} \ln P_m \]

\[ \ln Q_s = \ln b + E_s \ln P_d \]
Estimating the effects of a change in trade protection using this system requires two basic steps. First, price and quantity data are used, together with estimates of the elasticity parameters, to solve the equations for the unobservable constant intercept terms, ln $a$, ln $b$, and ln $c$. Then the estimates of the intercepts and the elasticity parameters are used, together with separately estimated changes in either the price or the quantity of the import due to a change in the level of protection ($t$), to calculate a new equilibrium and the comparative static welfare effects of the change. For this Briefing, we used the elasticity parameters provided in Hufbauer and Elliott (1994).

Suppose, for example, that a tariff or nontariff equivalent barrier is eliminated. By invoking the assumption that ln $Q_s$ equals ln $Q_d$, the equations may be solved to yield the new price of the domestic product as a function of the new import price.

$$\ln P_d' = \left(\ln a - \ln b\right)/\left(E_{dd} - E_{dd}\right) + \left[E_{dm}/\left(E_{dd} - E_{dd}\right)\right] \times \ln P_m'$$

Equations (1.5) and (1.6) may be solved to yield the two new prices: $P_m'$ and $P_d'$. In turn, these yield the output of the domestic product using the logarithm of equation (1.1). Once the change in output of the domestic product is calculated, the change in labor employed can be calculated, assuming a linear relationship between output changes and labor employed. The consumer cost can be calculated as the change in domestic price times the new quantity of domestic production. Together, these changes yield a consumer cost per job-year saved or created (see table A.1).
Table A.1
Effects of eliminating tariffs for textiles and apparel

<table>
<thead>
<tr>
<th><strong>Effects for textiles</strong></th>
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<tbody>
<tr>
<td>Consumer surplus gain (millions of dollars)</td>
<td>3,247</td>
</tr>
<tr>
<td>Producer surplus loss (millions of dollars)</td>
<td>468</td>
</tr>
<tr>
<td>Tariff revenue loss/quota rent loss (millions of dollars)</td>
<td>2,665</td>
</tr>
<tr>
<td>Efficiency gain (millions of dollars)</td>
<td>114</td>
</tr>
<tr>
<td>Employment loss (number of workers)</td>
<td>2,445</td>
</tr>
<tr>
<td>Cost per job saved or created (millions of dollars)</td>
<td>1.3</td>
</tr>
</tbody>
</table>

**Base-year data (2019)**

<table>
<thead>
<tr>
<th>Import price (P_m) (index)</th>
<th>1.00</th>
</tr>
</thead>
<tbody>
<tr>
<td>Import volume (Q_m) (millions of dollars)</td>
<td>38,070</td>
</tr>
<tr>
<td>Domestic price (P_d) (index)</td>
<td>1.00</td>
</tr>
<tr>
<td>Domestic output (Q_d) (millions of dollars)</td>
<td>49,600</td>
</tr>
<tr>
<td>Employment (production workers)</td>
<td>236,800</td>
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</tbody>
</table>

**Postliberalization estimates**

<table>
<thead>
<tr>
<th>Import price (P'_m) (index)</th>
<th>0.93</th>
</tr>
</thead>
<tbody>
<tr>
<td>Import volume (Q'_m) (millions of dollars)</td>
<td>41,322</td>
</tr>
<tr>
<td>Domestic price (P'_d) (index)</td>
<td>0.99</td>
</tr>
<tr>
<td>Domestic output (Q'_d) (millions of dollars)</td>
<td>49,130</td>
</tr>
<tr>
<td>Employment (production workers)</td>
<td>234,555</td>
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**Parameters**

<table>
<thead>
<tr>
<th>Elasticities</th>
<th>Constants</th>
</tr>
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<tbody>
<tr>
<td>Domestic demand own-price elasticity (E_{dd})</td>
<td>-0.60</td>
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<tr>
<td>Domestic demand cross-price elasticity (E_{dm})</td>
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<tr>
<td>Domestic supply own-price elasticity (E_{s})</td>
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<tr>
<td>Import demand own-price elasticity (E_{mm})</td>
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<tr>
<td>Import demand cross-price elasticity (E_{md})</td>
<td>1.30</td>
</tr>
</tbody>
</table>

**Effects for apparel**

| Consumer surplus gain (millions of dollars) | 10,157 |
| Producer surplus loss (millions of dollars) | 984 |
| Tariff revenue loss/quota rent loss (millions of dollars) | 8,662 |
| Efficiency gain (millions of dollars) | 511 |
| Employment loss (number of workers) | 6,265 |
| Cost per job saved or created (millions of dollars) | 1.6 |
### Base-year data (2019)

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
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</thead>
<tbody>
<tr>
<td>Import price (P_m) (index)</td>
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<tr>
<td>Import volume (Q_m) (millions of dollars)</td>
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<td>Domestic output (Q_d) (millions of dollars)</td>
<td>20,000</td>
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<td>Employment (production workers)</td>
<td>124,100</td>
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### Postliberalization estimates

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<tbody>
<tr>
<td>Import price (P'_m) (index)</td>
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<tr>
<td>Import volume (Q'_m) (millions of dollars)</td>
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<tr>
<td>Domestic price (P'_d) (index)</td>
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<td>Domestic output (Q'_d) (millions of dollars)</td>
<td>18,990</td>
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<td>Employment (production workers)</td>
<td>117,835</td>
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### Parameters

#### Elasticities

<table>
<thead>
<tr>
<th>Elasticity</th>
<th>Value</th>
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<tbody>
<tr>
<td>Domestic demand own-price elasticity (E_{dd})</td>
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<tr>
<td>Domestic demand cross-price elasticity (E_{dm})</td>
<td>1.18</td>
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<tr>
<td>Domestic supply own-price elasticity (E_s)</td>
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<tr>
<td>Import demand own-price elasticity (E_{mm})</td>
<td>-1.60</td>
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<tr>
<td>Import demand cross-price elasticity (E_{md})</td>
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</table>

#### Constants

<table>
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<tr>
<th>Constant</th>
<th>Value</th>
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<tbody>
<tr>
<td>(\ln a)</td>
<td>9.9</td>
</tr>
<tr>
<td>(\ln b)</td>
<td>9.9</td>
</tr>
<tr>
<td>(\ln c)</td>
<td>11.37</td>
</tr>
</tbody>
</table>

### Source

Authors’ calculations.
The Peterson Institute for International Economics gratefully acknowledges the support of the Koch Foundation for this project.