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By Rea S. Hederman Jr., Michael E. Reed, and Trevor Lewis

ECONOMIC RESEARCH CENTER
at THE BUCKEYE INSTITUTE

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The Obama Administration aggressively pursued environmental emissions targets aimed at power plants across the country—first legislatively with the help of a sympathetic Congress, then by executive order. The Obama-era's Environmental Protection Agency (EPA) ultimately issued its Clean Power Plan (CPP), which set stringent rules and emissions standards for energy producers. While the CPP was under legal challenge and judicial review, Donald Trump defeated Hillary Clinton for the presidency, and rolled back the CPP and related EPA directives, granting power plants an indefinite reprieve from the CPP's requirements. After spending seven years in legal limbo, the plaintiffs of *West Virginia v. EPA* petitioned the Supreme Court to review the CPP. In June 2022, the Supreme Court ruled that the EPA overstepped their legal authority in promulgating the CPP and vacated the regulation. Although the CPP is officially dead, the Biden Administration appears poised to revive it, reasserting environmental rules that will have significant, onerous effects on energy providers and the U.S. economy.

Facing a Republican House of Representatives that could stymie his legislative agenda, President Biden may rely heavily on executive orders and the EPA to promulgate new climate policy. On November 18, 2022, the White House announced $13 billion in Department of Energy (DOE) grant funding for expanding the nation's capacity to deliver affordable, clean electricity. These grants purport to improve the country's power grid and advance the president's emissions reduction goals. Unfortunately, the DOE grants pave the way for more CPP-style regulatory programs. Given the Biden Administration's interest in governing by EPA rule and executive orders, it is important to anticipate the foreseeable economic costs and benefits of moving away from fossil fuel and toward renewable energy sources: (1) the cost of additional wind- and solar-powered resources to meet CPP requirements; (2) the direct benefits of CPP compliance using a social cost of carbon calculation; and (3) the economic impacts of CPP requirements on Ohio and California, calculated using the Economic Research Center's (ERC) dynamic tax model.

With their robust economies, diverse geographies, and mixed population densities, California and Ohio illustrate how a new CPP will likely affect most of the country. Ohio's varied midwestern geography and climate, and its combination of urban-suburban-rural populations make it a suitable representative for much of the United States. California is similarly diverse, but its geography and climate are significantly more conducive than Ohio's to renewable power sources. Estimating the economic effects of a new CPP on Ohio and California therefore provides a more accurate picture of those potential effects on the rest of the nation.

To achieve President Biden's call to reduce carbon emissions 52% below 2005 levels, Ohio and California will have to close reliable, low-cost coal and natural gas power plants, and replace them with higher-cost, intermittent wind and solar power. Under a new CPP, Ohio will have to cut yearly emissions by 23 percent, or roughly 20 million tons of CO_2. By contrast, California will only need to reduce emissions by 10 percent, or six million tons of CO_2. But to achieve those respective results, both states will need to replace low-cost baseload coal and natural gas with higher cost wind and solar energy, which will raise electricity prices for businesses and families. Higher utility costs will then have negative effects that will ripple through the Ohio and California economies. We anticipate those effects under four reasonable scenarios, which reveal economies hemorrhaging jobs, production, and tax revenue over the next ten years. Discounting capital at a seven percent rate, for example, Ohio will lose 10,000 jobs; see its gross domestic product (GDP) fall by $3.19 billion, consumption decline by $550 million, investment drop by $1.99 billion, and tax revenue decline by $2.51 billion by 2032. Applying the seven percent discount rate to California over the same period, we estimate that a new CPP will cost the state 10,000 jobs, $5.11 billion in GDP, $1.87 billion in consumption, $3.1 billion in investments, and $1.87 billion in tax revenue.

When California's capital costs to build renewable energy sources are discounted at seven percent, we estimate that California households will see electricity rates rise by seven cents per kilowatt-hour (KWh). A typical California household will see a $665 annual increase in its electricity bill. Discounting Ohio's wind and solar capital costs at a seven percent rate shows a nine cents per KWh increase, which will cost an additional $810 per year per household for electricity. Discounting capital at three percent yields similarly disturbing results in both states and means that a revived Clean Power Plan poses grave economic risks to American households and businesses that should be critically assessed before being pursued.

INTRODUCTION

The Obama Administration aggressively pursued environmental emissions targets aimed at power plants across the country—first legislatively with the help of a sympathetic Congress, then by executive order. The Obama-era's EPA ultimately issued its CPP, which set stringent rules and emissions standards for energy producers. While the CPP was under legal challenge and judicial review, Donald Trump defeated Hillary Clinton for the presidency, and rolled back the CPP and related EPA directives, granting power plants a reprieve from the CPP's requirements. That reprieve may soon be over as the Biden Administration appears poised to revive the CPP and reassert environmental rules that will have significant, onerous effects on energy providers and the U.S. economy.

A brief history of the Clean Power Plan proves instructive as it may foreshadow rule-making tactics the Biden Administration may take following the Republican takeover of the House of Representatives in the 2022 election. As part of that history, it is worth revisiting the EPA's flawed calculations ostensibly supporting the CPP's requirements. First, the EPA failed to adhere to the Office of Management and Budget's (OMB) rigorous impact assessment standards in its treatment of the "social cost of carbon" (SCC). The SCC was crucial to ensuring that the CPP would pass the cost-benefit analysis insofar as it quantified "the social benefits of reducing carbon dioxide emissions into cost-benefit analyses of regulatory actions."[1] But the SCC's metrics were critically flawed and should have disqualified its use in any federal rule-making. Second, the CPP's original cost-benefit analysis compared the regulations' compliance costs against poorly quantified benefits. Despite failing to follow the OMB's basic reporting requirements, the EPA still used the debunked SCC numbers to extrapolate global climate benefits, which inflated the CPP's net benefits. The Biden Administration's EPA may well repeat those mistakes.

Facing a Republican House of Representatives that could stymie his legislative agenda, President Biden may rely on executive orders and the EPA to promulgate new climate policy. On November 18, 2022, the White House announced $13 billion in DOE grant funding for expanding the nation's capacity to deliver affordable, clean electricity. These grants purport to improve the country's power grid and advance the president's emissions reduction goals. Unfortunately, the

[1] ***Technical Support Document: Technical Update of the Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12866***, U.S. Environmental Protection Agency, August 2016.

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With their robust economies, diverse geographies, and mixed population densities, California and Ohio exemplify how a new CPP will likely affect most of the country. Ohio's varied midwestern geography and climate, and its combination of urban-suburban-rural populations make it a suitable representative for much of the United States. California is similarly diverse, but its geography and climate are significantly more conducive than Ohio's to renewable power sources. Estimating the economic effects of a new CPP on Ohio and California therefore provides a more accurate picture of those potential effects on the rest of the nation.

History of the Clean Power Plan and the Affordable Clean Energy Rule

The history of the CPP begins with the death of the American Clean Energy and Security (ACES) Act. In 2009, President Barack Obama proposed cutting national carbon emissions to 17 percent below 2005 levels. Congress adopted the president's proposed target and incorporated it into the ACES Act, which then would have required establishing a cap-and-trade system and minimum zero-emissions renewable energy mandates for power providers. Although the ACES Act passed the Democrat-controlled House of Representatives, the bill stalled in the Senate where the Republican minority successfully filibustered to prevent its passage until the Republicans reclaimed the House and Senate in 2010, and thereby killed any chance that the bill would become law.

The day after the fateful midterm elections, President Obama restated his determination to enact climate regulation and foreshadowed future federal action: "cap and trade was just one way of skinning the cat; it was not the only way."[2] With the legislative path closed off indefinitely, the Obama Administration would look for new ways to reach its climate policy goals. Three years later, in June 2013, President Obama's Climate Action Plan directed the U.S. EPA to revise emission standards for energy infrastructure, with the tacit goal of gradually regulating coal power plants out of existence and replacing them with zero-emission renewable energy.[3] One year later, the EPA unveiled the Carbon Pollution Emission Guidelines for Existing Stationary Sources: Electric Utility Generating Units.[4] The proposed rule included President Obama's emissions targets and several ACES Act holdover rules.[5] The new regulatory "guidelines" circumvented bipartisan congressional approval and effectively gave the EPA unilateral control over environmental regulation.

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[2] **Press Conference by the President**, The White House Office of the Press Secretary, November 3, 2010.
[3] **FACT SHEET: President Obama's Climate Action Plan**, The White House Office of the Press Secretary, June 25, 2013; **The President's Climate Action Plan**, Executive Office of the President, June 2013.
[4] Environmental Protection Agency, **Carbon Pollution Emission Guidelines for Existing Stationary Sources: Electric Utility Generating Units**, Federal Register, October 26, 2014.
[5] *Ibid.*

The EPA rule calculated three state-specific emissions limitation metrics and required states then to choose one by which to be judged:[6] (1) "a rate-based state goal measured in pounds per megawatt hour (lb./MWh)"; (2) "A mass-based state goal measured in total short tons of carbon dioxide (CO_2)"; (3) "A mass-based state goal with a new source of complement measured in total short tons of CO_2."[7] After selecting an emissions metric, states then needed to draft and implement a plan for a best system of emission reduction (BSER). Emission reduction plans would use any combination of the EPA's prescribed building blocks included in the BSER: (1) heat rate improvements at existing coal and natural gas-fired power plants; (2) replacing coal fired-power plants with cleaner burning natural gas power plants; (3) the number of sources for zero-emission renewable energy; (4) decreasing electricity demand by increasing end-use efficacy.[8]

The first building block required existing coal and natural gas power plants to reduce emissions by increasing the efficiency of heat exchange. Building blocks two and three formed a "generation shifting" strategy that gradually replaced coal-fired power plants with new natural gas-fired power plants and zero-emission sources of electricity.[9] The fourth building block would have reduced demand for electricity by rolling out energy efficiency measures,[10] but it was omitted because states would likely include energy efficiency as "a significant component of [their] plans under the [proposed regulation]."[11]

The EPA claimed that section 111(d) of the Clean Air Act (CAA) gave it complete regulatory authority over the air and all the particulates that went into it, regardless of their origin, and thus it had statutory authority to regulate coal-fired power plants.[12] Some states, however, disputed the EPA's interpretation.

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[6] U.S. Environmental Protection Agency, **Carbon Pollution Emission Guidelines for Existing Stationary Sources: Electric Utility Generating Units**, Federal Register, October 26, 2014; **FACT SHEET: OVERVIEW OF THE CLEAN POWER PLAN**, U.S. Environmental Protection Agency, January 19, 2017.

[7] **FACT SHEET: OVERVIEW OF THE CLEAN POWER PLAN**, U.S. Environmental Protection Agency, August 2015.

[8] *Ibid*.

[9] ***Am. Lung Ass'n v. Env't Prot. Agency*, 985 F.3d 914, 930 (D.C. Cir. 2021), rev'd and remanded sub nom. *West Virginia v. Env't Prot. Agency*, 142 S. Ct. 2587 (2022)**.

[10] Rishi Garg, **The U.S. EPA's Clean Power Plan: A Comprehensive Summary**, National Regulatory Research Institute, 2014.

[11] **FACT SHEET: Key Changes and Improvements from Proposal to Final**, U.S. Environmental Protection Agency, August 2015.

[12] **42 U.S.C. § 7441**.

On June 18, 2014, West Virginia and 16 other states' attorneys general submitted a public comment that challenged the EPA's interpretation and use of Section 111(d) for promulgating the EPA's proposed rule.[13] The states argued that the CPP overrode "states' energy policies and [imposed] a national energy and resource-planning policy that picks winners and losers based solely on EPA's choices, forcing states to favor renewable energy sources and demand-reduction measures over fossil fuel-fired electric production."[14] And they highlighted the CPP's "numerous legal defects, each of which, provides an independent basis to invalidate the rule in its entirety."[15] The EPA did not address any of the points raised in states' public comment, ensuring that these matters would be resolved in court after the regulation's promulgation.

In June 2015, the EPA announced the final rule for the CPP, setting a total emissions reduction target of 32 percent below 2005 levels, which would require a more aggressive energy transition than anticipated.[16] Legal challenges followed swiftly.

On October 23, 2015, West Virginia, joined by 26 other states, myriad trade associations, rural electric co-ops, and other organizations, filed a petition for review of the CPP in the United States Court of Appeals for District of Columbia Circuit.[17] Without waiting for the review to be completed West Virginia and twenty-nine other states and state agencies filed an application for an immediate stay of the CPP with the Supreme Court on January 26, 2016.[18] The U.S. Supreme Court granted the stay on February 9, 2016.[19]

But before the cases were argued, Donald Trump became president in 2016, having campaigned to end onerous environmental regulations, including the CPP.[20] On March 3, 2017, President Trump signed Executive Order 13783, which called for the Environmental Protection Agency to "immediately take all steps necessary to review the final rules… [and] rescind the guidance" for the CPP.[21] With the

[13] **FACT SHEET: Clean Power Plan By the Numbers**, U.S. Environmental Protection Agency, August 2015.
[14] **FACT SHEET: Clean Power Plan By the Numbers**, U.S. Environmental Protection Agency, August 2015; 17 State Attorneys General, **Comment Letter on Proposed EPA Carbon Pollution Emission Guidelines for Existing Stationary Sources: Electric Utility Units** (November 24, 2014).
[15] *Ibid.*
[16] *Ibid.*
[17] Pet. for Review, ***West Virginia v. Env't Prot. Agency***, No. 15-1363 (D.C. Cir. Oct. 23, 2015).
[18] Appl. for Stay, ***West Virginia v. Env't Prot. Agency***, 577 U.S. 1126 (2016) (No. 15A773)
[19] Order Granting Stay, ***West Virginia v. Env't Prot. Agency***, 577 U.S. 1126 (2016) (No. 15A773).
[20] Robert Walton, **Trump Vows to Scrap Clean Power Plan**, Utility Dive, September 23, 2016.
[21] **Exec. Order No. 13783, 82 Fed. Reg. 61** (March 31, 2017).

regulatory measure facing imminent repeal, the Supreme Court was in no rush to rule on *West Virginia v. EPA*.

On October 10, 2017, the Trump Administration's EPA released its regulatory impact analysis for the review of the CPP. The EPA report raised concerns about the uncertainty in the modeling and metrics dealing with "demand-side energy efficiency investments"[22], "health benefits estimations, including those associated with using a benefits-per-ton approach"[23], and "characterization of uncertainty in monetizing climate-related benefits" [24] in the CPP's original regulatory impact analysis (RIA). The EPA's examination of the national power sector revealed that greenhouse gas (GHG) emissions were "already below the requirements set forth under the CPP."[25] The report concluded "there is likely to be no difference between a world where the CPP is implemented and one where it is not,"[26] calling into question whether the CPP was even needed.

Given that the electricity sector was already on track to achieve the CPP's original goals,[27] the Trump Administration's EPA concluded that repealing the CPP would have a nugatory effect on the economy. Additionally, the RIA proposed adopting a new rule that focused on reducing emissions through specific modifications at existing power plants. The EPA returned on August 21, 2018, to formally repeal the CPP and propose the CPP's replacement: the Affordable Clean Energy (ACE) rule.[28]

The ACE rule adopted a BSER for achieving emissions standards as prescribed by CAA Section 111(d), but it eliminated the CPP's building blocks. According to the ACE rule's RIA, the CPP's building blocks were treated as "different groups of technologies (blocks) that were used to establish state level CO_2 emission goals."[29] Without a consistent strategy, the CPP benefits were difficult to model. Instead, the ACE rule's BSER included seven heat rate improvement (HRI) technologies.[30]

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[22] **Regulatory Impact Analysis for the Review of the Clean Power Plan**, U.S. Environmental Protection Agency, October 2017.
[23] *Ibid.*
[24] *Ibid.*
[25] **Regulatory Impact analysis for the Repeal of the Clean Power Plan, and the Emission Guidelines for Greenhouse Gas Emissions from Existing Electric Utility Generating Units**, U.S. Environmental Protection Agency, June 2019.
[26] *Ibid.*
[27] *Ibid.*
[28] **FACT SHEET: The Affordable Clean Energy Rule (ACE)**, U.S. Environmental Protection Agency, June 2019.
[29] *Ibid.*
[30] EPA, **Regulatory Impact Analysis for the Repeal of the Clean Power Plan, and the Emission Guidelines for Greenhouse Gas Emissions from Existing Utility Generating**

Site specific improvements made it easier for the EPA to implement, model, and quantify the positive impacts of the ACE rule.

On July 8, 2019, the EPA announced the full repeal of the CPP and finalization of the ACE rule.[31] The American Lung Association and the American Public Health Association promptly sued the EPA.[32] On January 19, 2021, the District of Columbia Circuit Court ruled in favor of the plaintiffs in *American Lung Association and American Public Health Association v. EPA*. The D.C. Circuit Court vacated the ACE rule because "the ACE Rule and its embedded repeal of the Clean Power Plan rested critically on a mistaken reading of the Clean Air Act."[33] The court, however, did not reinstate the CPP.[34] The EPA did not argue for the CPP's reinstatement because "ongoing changes in electricity generation mean that the emission reduction goals that the CPP set for 2030 have been achieved."[35] Without any further action from the EPA or pending litigation, the Supreme Court's 2016 stay of the CPP remained in effect.

Over the seven-year period when the CPP was held in abeyance, free market forces proved capable of guiding the power generation sector towards lower emission fuels without any functional regulation. GHG and other harmful emissions fell at a faster rate than what the CPP had modeled. SO_2 emissions declined by 37 percent, NO_x emissions by 35 percent, and CO_2 15 percent.[36] The decline in aggregate power sector emissions was triggered by a precipitous drop in natural gas prices that coincided with the shale revolution. Abundant natural gas was cheap, and many utilities replaced old coal-powered plants with more efficient, cheaper natural gas-

Units, June 2019; **FACT SHEET: The Affordable Clean Energy Rule (ACE)**, U.S. Environmental Protection Agency, June 2019.

[31] **Fact Sheet: Revised CAA Section 111(d) Implementing Regulations**, U.S. Environmental Protection Agency, June 2019; EPA Finalizes Affordable **Clean Energy Rule, Ensuring Reliable, Diversified Energy Resources while Protecting our Environment**, U.S. Environmental Protection Agency Press Office, June 19, 2019; **Affordable Clean Energy Rule**, West Virginia Department of Environmental Protection, December 23, 2020.

[32] Pet. for Review, ***Am. Lung Ass'n v. Env't Prot. Agency***, 985 F.3d 914 (D.C. Cir. 2021) (No. 19-1140).

[33] ***Am. Lung Ass'n v. Env't Prot. Agency*, 985 F.3d 914, 930 (D.C. Cir. 2021), rev'd and remanded sub nom. *West Virginia v. Env't Prot. Agency*, 142 S. Ct. 2587 (2022)**.

[34] *Ibid.*

[35] Joseph Goffman, **Status of Affordable Clean Energy Rule and Clean Power Plan**, U.S. Environmental Protection Agency, February 21, 2021.

[36] **U.S. Emissions, Electric Power Industry, MMT CO_2 eq (2010 – 2020)**, U.S. Environmental Protection Agency Greenhouse Gas Inventory Data Explorer (Last visited November 29, 2022); **Annual Percent Change of Emissions, 1995 – 2021**, U.S. Environmental Protection Agency Power Plant Emission Trends (Last visited November 29, 2022).

fired power plants.[37] Cheap natural gas put America's power sector on course to exceed the CPP's 2030 emissions goals.[38]

In April 2021, the plaintiffs in *West Virginia v. EPA* asked the Supreme Court to resolve and redress the initial 2015 arguments over the CPP.[39] On June 30, 2022, the Supreme Court, in a five-to-four decision, held that the EPA had overstepped the regulatory authority conferred by CAA Section 111(d). After a seven-year legal battle, the CPP and ACE rules had been laid to rest.

[37] Chris Davis, L. Andrew Bollinger, and Gerard P.J. Dijkema, "**The state of the states: Data-driven analysis of the US Clean Power Plan**," *Renewable and Sustainable Energy Review*, Volume 60, July 2016, p. 631–652.
[38] **FACT SHEET: OVERVIEW OF THE CLEAN POWER PLAN**, U.S. Environmental Protection Agency, January 19, 2017; **Regulatory Impact Analysis for the Review of the Clean Power Plan**, U.S. Environmental Protection Agency, October 2017.
[39] Pet. for Writ of Cert., ***West Virginia v. Env't Prot. Agency***, 142 S. Ct. 2587 (2022) (No. 20-1530).

The Social Cost of Carbon

The SCC was the EPA's linchpin for ensuring the CPP's RIA would pass the benefit's cost analysis (BCA). But the group responsible for calculating the SCC failed to adhere to OMB's rigorous RIA requirements. This should have disqualified the SCC in any federal RIA.

In 2009, the Obama Administration EPA formed an interagency working group (IWG) for assessing the incremental damages associated with carbon dioxide.[40] The IWG produced the Technical Support Document (TSD): Social Cost of Carbon for Regulatory Impact Analysis (TSD 2010),[41] which provided quantifiable damage estimates for CO_2 that the EPA and other federal agencies needed for the BCA.[42]

The EPA needed the SCC to quantify the "the social benefits of reducing carbon dioxide emissions into cost-benefit analyses of regulatory actions."[43] Putatively, the SCC accounts for all "changes in net agricultural productivity, human health, property damages . . . and the value of ecosystem services due to climate change."[44] It handed regulatory agencies a tool for overstating regulatory benefits. But the SCC does not follow the OMB's rigorous standards.

For any regulation with significant economic impacts, the OMB requires a full RIA with a comprehensive BCA.[45] As the "primary tool" of an RIA, the BCA must quantify and express all domestic benefits and costs in monetary units.[46] Given the importance of BCA, it logically follows that the RIA metrics should be held to the same standards. When a regulation's benefits are spread across many years, the OMB requires the BCA to discount the cost of the regulation. Because people prefer to consume in the present and defer costs to the future, future costs need to be adjusted into present dollar amounts. Discounting future costs helps regulators and lawmakers assess whether investing now to mitigate future damages is worth

[40] **Request for Nominations of Experts for the Review of Technical Support Document for the Social Cost of Greenhouse Gases**, Federal Register, January 25, 2022.
[41] **Technical Support Document: Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12866**, Interagency Working Group on Social Cost of Carbon, February 2010.
[42] *Ibid.*
[43] ***Technical Support Document: Technical Update of the Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12866***, U.S. Environmental Protection Agency, August 2016.
[44] *Ibid.*
[45] OMB Circular A-4, **Regulatory Impact Analysis**, September 17, 2003.
[46] *Ibid.*

the foregone consumption in the present. The cost of the future damages varies with the discount rates. Lower discount rates carry greater future damages.[47] Calculating future damages at higher discount rates lowers the cost of future damages and lessens the need for immediate regulation. Given the significance of quantifying costs, the OMB is solicitous about the discount rates used in an analysis.

The OMB prescribes two real discount rates for estimating the time value of money: three percent and seven percent.[48] The seven percent discount rate is the base-case for all RIAs and reflects the average rate of return on private investment capital. Over the last 200 years, the U.S. stock market has generated a seven percent rate of return,[49] And seven percent is the average return on small business and corporate capital.[50] When the benefits of a regulation directly impact private consumption, the OMB acknowledges that a lower discount rate is appropriate. The OMB recommends a three percent discount rate, reflecting the average rate of return of the bond market.[51] Although the OMB permits RIAs to include niche discount rates for corporate capital—which is generally discounted at 10 percent,[52] and intergenerational benefits, which use a discount range between one and three percent—such rates are supposed to be used "in addition to calculating net benefits using discount rates of three percent and seven percent."[53] Notably, the IWG failed to produce a cost estimate for the seven percent discount rate from the SCC.

Although the IWG believed that a lower discount rate is necessary to quantify inter-generational damages, its argument skewed toward the negative aspects of climate change and undercounted inter-generational benefits. Since the SCC's initial calculation, more farmers in America's heartland have double planted soy and wheat crops.[54] Agricultural benefits like these were not included in the SCC because the models used to calculate the SCC were not properly calibrated to quantify the agricultural benefits associated with higher atmospheric

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[47] Paul C. "Chip" Knappenberger, **An Example of the Abuse of the Social Cost of Carbon**, Cato at Liberty, August 23, 2013.
[48] OMB Circular A-4, **Regulatory Impact Analysis**, September 17, 2003.
[49] David Kreutzer, **Discounting Climate Change**, The Heritage Foundation, June 16, 2016.
[50] OMB Circular A-4, **Regulatory Impact Analysis**, September 17, 2003.
[51] *Ibid.*
[52] *Ibid.*
[53] *Ibid.*
[54] Christopher A Seifert and David B Lobell, "**Response of double cropping suitability to climate change in the United States**," Environ, 2015; Matthew Gammans, Pierre Merel, and Ariel Ortiz-Bobea, "**Double Cropping as and Adaptation to Climate change in the United States**," Department of Agriculture and Resource Economics, University of California, Davis, January 6, 2020.

concentrations of CO_2.[55] By not including the seven percent discount rate in SCC, the IWG failed to provide regulatory agencies with a reliable metric to quantify climate damages.

Using the Dynamic Integrated Climate-Economy (DICE) integrated assessment model (IAM), the IWG computed SCC using 2.5 percent, three percent, and five percent discount rates. Michael Greenstone, a former member of the IWG, has defended discount rates as low as two percent, likening investment now into climate mitigation to "investing in gold before the great recession."[56] For those who favor the lower discount rate, the negative intergenerational benefit measured at lower discount rates trumps the need for a thorough cost benefit analysis,[57] and they seem unpersuaded by critics who have found that the SCC is positive at higher discount rates. In his Senate testimony, however, Dr. Robert P. Murphy highlighted at "a discount rate of five percent, more than a fifth of the computer simulations reported a SCC that was near-zero or even negative . . . for the year 2020."[58] Murphy posited that if the IWG had used "a 7 percent discount rate and an earlier reference year . . . a larger fraction of simulations would register zero or negative values for the SCC."[59] The Heritage Foundation's energy and environmental policy experts, Drs. Kevin Dayaratna[60] and David W. Kreutzer, subsequently confirmed Murphy's suspicion.

Dayaratna and Kreutzer used the DICE model to estimate the seven percent discount rate, which returned "a markedly lower estimate" for the SCC.[61] The scholars also showed that the EPA's DICE and FUND climate models failed to produce reliable, statistically sound results, making any purported social cost of air pollution quantified by these models inherently suspect.

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55 Kevin D. Dayaratna, Ross McKitrick, and Patrick J. Michaels, "**Climate sensitivity, agricultural productivity and the social cost of carbon in FUND**," Environmental Economics and Policy Studies, 22, p. 433–448, 2020.

56 Michael Greenstone, **What Financial Markets Can Teach Us About Managing Climate Risks**, The New York Times, April 4, 2017.

57 Michael Greenstone and James H. Stock, **The Right Discount Rate for Regulatory Costs and Benefits**, *The Wall Street Journal*, March 4, 2021.

58 Robert P. Murphy, Senior Economist, Institute for Energy Research, testimony before the U.S. Senate Committee on Environment and Public Works, 113th Congress "**The Social Cost of Carbon**," 2013.

59 *Ibid.*

60 Kevin D. Dayaratna, Senior Statistician and Research Programmer, The Heritage Foundation, testimony before the U.S. House of Representatives Subcommittee on Environment and Oversight, Committee on Science and Technology, "**At What Cost? Examining the Social Cost of Carbon**," February 24, 2017.

61 David W. Kreutzer, Ph.D. and Kevin Dayaratna Ph.D., **Scrutinizing the Social Cost of Carbon: Comment to the Energy Department**, The Heritage Foundation, September 16, 2013.

THE CLEAN POWER PLAN'S FLAWED COST-BENEFIT ANALYSIS

The CPP's original BCA compared the regulations' compliance costs against poorly quantified benefits. Despite failing to follow the OMB's basic reporting requirements for RIAs, the EPA still used the debunked SCC metrics to extrapolate the global climate benefits of reducing CO_2 emissions, which substantially inflated the CPP's net benefits. The CPP's benefits were calculated by combining all four SCC estimates with all health co-benefits and then applying the OMB three percent and seven percent discount rate. The CPP's RIA reported annualized benefits in 2030 ranging from $26 to $45 billion.[62]

The CPP's main benefits were health co-benefits and climate benefits. By reducing harmful air particles, the CPP purportedly would reduce climate caused illnesses and deaths. The EPA estimated "3,600 premature deaths, 1,700 heart attacks, 90,000 asthma attacks, and 300,000 missed work and school days" would be eliminated by better air quality.[63] The monetized aggregate of all health co-benefits fell between $14 and $34 billion.[64] The EPA estimated that the CPP would generate $20 billion in climate benefits by 2030 for mass- and rate-based approaches.[65] These climate benefits were reported at the three percent discount rate.

The EPA estimated that electricity providers and states would pay $8.4 billion in compliance costs. That estimate, however, included the costs of adopting the regulation and used a five percent discount rate. By calculating compliance costs at a higher discount rate than the climate benefits, the EPA dulled the regulatory costs while further increasing the already inflated benefits.

SCC measures the *global* damages of CO_2 emissions even though the OMB explicitly states that benefits should "accrue to citizens and residents of the United States."[66] The EPA argued that the CPP would benefit some nine million Americans

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[62] **FACT SHEET: OVERVIEW OF THE CLEAN POWER PLAN**, U.S. Environmental Protection Agency, August 2015.
[63] *Ibid.*
[64] *Ibid.*
[65] At a three percent discount rate. Climate benefits at the higher five percent discount rate were $6.4 million by 2030. A seven percent discount rate would have netted even fewer climate benefits; **Regulatory Impact Analysis for the Clean Power Plan Final Rule**, U.S. Environmental Protection Agency, October 23, 2015.
[66] OMB Circular A-4, **Regulatory Impact Analysis**, September 17, 2003.

living abroad by reducing global emissions[67] to justify including global climate benefits in its final net benefits calculation. The average global temperature benefit was not included in the RIA.[68]

The EPA estimated that the CPP would eliminate 30,900 to 33,700 jobs-years in the electricity, coal, and natural gas sectors by 2030.[69] Unfortunately, it did not include additional, more comprehensive estimates of the regulation's economic costs. Other organizations, however, made those broader calculations. The Heritage Foundation, for example, estimated that by 2030 the CPP would reduce personal income by $7,000 per person, cost the United States 500,000 manufacturing jobs, and pare the national GDP by more than $2.5 trillion.[70] The Heritage Foundation's findings, however, were on the extreme end of the damage estimates. The EIA found that average annual income for a family of four would gradually decline, peaking at $1,700 in 2025, before gradually increasing but never recovering to pre-CPP levels.[71] This fall in family income coincided with declines in GDP ranging from 0.17 percent to 0.25 percent between 2015–2040.[72] These deceptively small percentages translated to huge declines in real GDP, with annual declines reaching a nadir of $147 billion in 2025 under the CPP base case. The U.S. Chamber of Commerce's study found results were close to the EIA's. The Chamber of Commerce reported the CPP "would suppress average annual U.S. GDP by $51 billion." By 2030, national annual GDP decline would peak at $104 billion and there would be 224,000 jobs fewer jobs.[73] The Chamber of Commerce also found that consumers will pay nearly $17 billion more per year for electricity under the CPP.[74] Although CPP cost and employment estimates vary, there is consensus that the CPP's climate benefits would come at huge economic costs that dwarfed the CPP's purported benefits.

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[67] **Regulatory Impact Analysis for the Clean Power Plan Final Rule**, U.S. Environmental Protection Agency, October 23, 2015.

[68] Benjamin Zycher, **President Obama's Clean Power Plan: All Cost, No Benefit**, RealCearMarkets, August 5, 2015.

[69] **Regulatory Impact Analysis for the Clean Power Plan Final Rule**, U.S. Environmental Protection Agency, October 23, 2015.

[70] Kevin D. Dayaratna, Ph.D., Nicolas D. Loris, and David W. Kreutzer, PhD., **Backgrounder No. 2975: The Obama Administration's Climate Agenda: Underestimated Costs and Exaggerated Benefits**, The Heritage Foundation, November 13, 2014.

[71] Kevin Dayaratna, Chief Statistician, The Heritage Foundation, testimony before the Committee on Science, Space, and Technology, "**The Economic Impact of the Clean Power Plan**," June 24, 2015.

[72] **Analysis of the Impacts of the Clean Power Plan**, U.S. Energy Information Administration, May 22, 2015.

[73] ***Assessing the Impact of Potential New Carbon Regulations in the United States***, U.S. Chamber of Commerce, May 2014.

[74] *Ibid.*

fuel industry.[75] Although CPP cost and employment estimates vary, there is consensus that the CPP's climate benefits would come at huge economic costs that dwarfed the CPP's purported benefits.

[75] **Regulatory Impact Analysis for the Clean Power Plan Final Rule**, U.S. Environmental Protection Agency, October 23, 2015.

THE CLEAN POWER PLAN'S SECOND WIND

The Obama Administration's Clean Power Plan included subsidies for zero-emission renewable energy that distorted price signals for utility scale solar and wind power, "[perpetuating a] false choice between renewables and natural gas,"[76] and led utilities to pursue renewables that were not economically viable. Additionally, the final version of the CPP included a pseudo-cap and trade emissions trading scheme designed to accelerate the build out of renewables in states with geographies favorable to wind and solar: *e.g.*, California and Texas. States that built out renewable sources of power could trade their credits to high-polluting states with maladapted geographies for renewable energy.[77] Without these incentives distorting the market prices of renewable energy, utilities would have pushed towards natural gas power plants because abundant shale gas was the most economical choice for electric utility generation.[78] Wind and solar energy just could not compete anywhere at any price point with natural gas.[79]

The Obama Administration eventually warmed to natural gas power plants for politically expedient reasons. Of all fossil fuel-fired power plants, natural gas plants emit the least GHGs,[80] which allowed the Obama Administration to keep the American electricity sector on track to meet and exceed the CPP's emission reduction targets.

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[76] **ANGA: In Order to Work, the Clean Power Plan Must Recognize Essential Natural Gas Role**, Fuels Market News, August 3, 2015.

[77] **FACT SHEET: OVERVIEW OF THE CLEAN POWER PLAN**, U.S. Environmental Protection Agency, January 19, 2017.

[78] Wesley J. Cole, Kenneth B. Medlock, and Aditya Jani, "**A view to the future of natural gas and electricity: An integrated modeling approach**," *Energy Economics*, Volume 60, Issue C (November 2016), p. 486–496; Akira Yanagisawa, ***Impacts of shale gas revolution on natural gas and coal demand***, Energy Demand, Supply and Forecast Group Energy Data and Modelling Center, January 2013; Jeffrey Logan, Garvin Heath, Jordan Macknick, Elizabeth Paranhos, William Boyd, and Ken Carlson, ***Natural Gas and the Transformation of the U.S. Energy Sector: Electricity***, Joint Institute for Strategic Energy Analysis, November 2012.

[79] Andrew K. Cohen, **The Gas Paradox: Assessing the Impacts of the Shale Gas Revolution on Electricity Markets and Climate Change**, working paper, Mossavar-Rahmani Center For Business and Government, Harvard University, May 2013.

[80] **Natural Gas Explained**, U.S. Energy Information Administration, November 7, 2022.

But natural gas is a fossil fuel and anathema to climate activists within the Democratic Party.[81] Activist pressure has prompted the Biden Administration to pursue a series of aggressive climate policies that closely resemble the Clean Power Plan's initial emissions targets. The Biden Administration announced in 2021 that the United States would need to reduce GHG emissions by 50-52 percent below 2005, by 2030[82]—a policy shift that will incentivize further federal subsidies, expand renewable energy programs, and reduce reliance on natural gas. The Infrastructure Investment and Jobs Act directed the Energy Information Administration to examine whether "the potential use of levelized cost of carbon abatement or a similar metric in analyzing generators of electricity . . . is feasible and the impact of incorporating levelized cost of carbon abatement in long-term forecasts."[83] And the Inflation Reduction Act (IRA),[84] touted as utility cost-reduction legislation, includes regulatory mandates, tax breaks, investment credits, and other incentives for expanding the green energy footprint.[85] Section 1706 of the IRA, for example, creates the U.S. DOE Infrastructure Reinvestment (EIR) Program designed to "revitalize current infrastructure at the pace needed to address the climate crisis."[86]

The IRA's renewable energy production tax credit, business energy investment tax credit, and advanced manufacturing tax credits are all subsidies to the green energy industry. The IRA's subsidies, tax credits, and development loans distort the true costs of green energy projects, and push expensive green energy on poor communities without assessing geographic viability.

With a Republican majority now in the House of Representatives, most expect President Biden to rely on executive orders and the EPA to promulgate new climate policy. On November 18, 2022, the White House announced $13 billion in DOE grant funding for expanding the nation's capacity to deliver affordable, clean

[81] Benjamin Hmiel et al., "**Preindustrial $^{14}CH_4$ indicates greater anthropogenic fossil CH_4 emissions**," Nature, 578, (February 2020) p. 409–412; **Why natural gas is dangerous for the climate**, Global Witness, March 4, 2021.

[82] **FACT SHEET: President Biden Sets 2030 Greenhouse Gas Pollution Reduction Target Aimed at Creating Good-Paying Union Jobs and Securing U.S. Leadership on Clean Energy Technologies**, The White House, April 22, 2021.

[83] **H.R.3684 – Infrastructure Investment and Jobs Act**, Congress.gov, June 4, 2021.

[84] **H.R.5376 – Inflation Reduction Act of 2022**, Congress.gov, September 27, 2021.

[85] United States Department of Treasury, **Request for Comments on Certain Energy Generation Incentives**, October 5, 2022.

[86] **Inflation Reduction Act of 2022 (IRA): Department of Energy Loan Guarantee Programs**, Congressional Research Service, August 5, 2022.

electricity.[87] Initially part of the Infrastructure Investment and Jobs Act,[88] these grants purport to improve the country's power grid and advance the president's emissions reduction agenda. Unfortunately, the DOE grants pave the way for more CPP-like market-distorting programs that will "reduce financial challenges by encouraging and de-risking additional investment."[89] The Biden Administration's commitment to reduce emissions signals that a CPP-style regulatory regime may loom on the horizon.

[87] **Fact Sheet: The Biden-Harris Administration Advances Transmission Buildout to Deliver Affordable Clean Electricity**, The White House, November 18, 2022.
[88] **Department of Energy: Request for Information of Grid Resilience and Innovation Partnerships Program**, Federal Register, September 7, 2022.
[89] *Ibid.*

The Full Cost of a More Expensive Energy Policy: Shifting from Fossil Fuel to Renewable Energy

Given the Biden Administration's interest in reviving a CPP-style regulatory regime that governs by EPA rule and executive orders, it is important to anticipate the foreseeable economic costs and benefits of moving away from fossil fuel and toward renewable energy sources: (1) the cost of additional wind- and solar-powered resources to meet CPP requirements; (2) the direct benefits of CPP compliance using a social cost of carbon calculation; and (3) the economic impacts of CPP requirements on Ohio and California, calculated using the Economic Research Center's dynamic tax model. Given their economies, diverse geographies, and population densities, California and Ohio exemplify how a new CPP will likely affect most of the country. Ohio's varied midwestern geography and climate, and its mix of urban-suburban-rural populations make it a suitable representative for much of the United States. California is similarly diverse, but its geography and climate are significantly more conducive to renewable power. Estimating the economic effects of a new CPP on Ohio and California provides a more accurate picture of those effects on the rest of the nation.

The Methodology

To estimate the cost of additional wind- and solar-powered energy sources under a new Clean Power Plan we assume that the new CPP contains the same percentage differences between intermediate and final carbon emission targets allowed for each state as the old CPP. To calculate the fossil fuel power replaced by wind and solar power to meet the new CPP requirements, we use the new targets and power generation data from EIA on carbon emissions by technology. We also use historic generation trends to forecast power generation to 2035. In order to satisfy the new CPP requirements, this report assumes that all increased electricity demand will be generated by wind and solar power sources.

The cost of new wind and solar power generation is based on the amount of power derived from replacing fossil generation and growth in consumption. For each generation forecast year, the amount of substitute and growth power is determined. Using data from the National Renewable Energy Laboratory Annual Technology Baseline (ATB), the number of wind turbines and size of utility solar panel systems is determined.[90] Additional data from the ATB are used to estimate the capital and operating costs for the wind/solar systems. Those costs are time dependent, matching the forecast growth and assumed straight line carbon emission requirements. Discount rates of seven and three percent are used to calculate a net present value (NPV) for these costs. The NPV values are used in determining the benefit/cost ratio of various scenarios.

To calculate the direct benefits of CPP compliance we use the power replaced and growth from the cost calculation to determine the amount of carbon emissions avoided by using wind and solar energy to replace fossil generation and support power growth. We use multiple values for the social cost of carbon to match the values used in the original CPP RIA. We use a value of $185/ton CO_2 based on a Resources for the Future/Berkley report.[91] Once the amount of avoided CO_2 emissions is known, we multiply these values by the SCC to determine direct benefits of the new CPP. Like the cost values, the benefits are calculated over time and a NPV is determined.

Finally, using the ERC's state macroeconomic tax model, we assume that the cost (capital and operating cost) of new wind and solar energy will be passed to individual and corporate electricity consumers. These costs flow through as individual income and corporate tax increases split evenly between the categories. The tax revenue generated by these "tax increases" is not sent to the government. Instead, this "revenue" is treated as a shift in spending allocation to pay the higher electricity bills that result from implementing a new CPP. Installing new wind and solar power generation occurs over time, so the "tax increases" also occur over time.

The Results

The EPA's RIA prepared for the Clean Power Plan in 2015 guides our results calculation.[92] The first set of calculations determines the amount of wind and solar power needed to satisfy a new CPP. The amount of infrastructure needed informs capital and operating cost estimates, which then represent the cost part of a

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[90] National Renewable Energy Laboratory, **Annual Technology Baseline** (Last visited December 5, 2022).

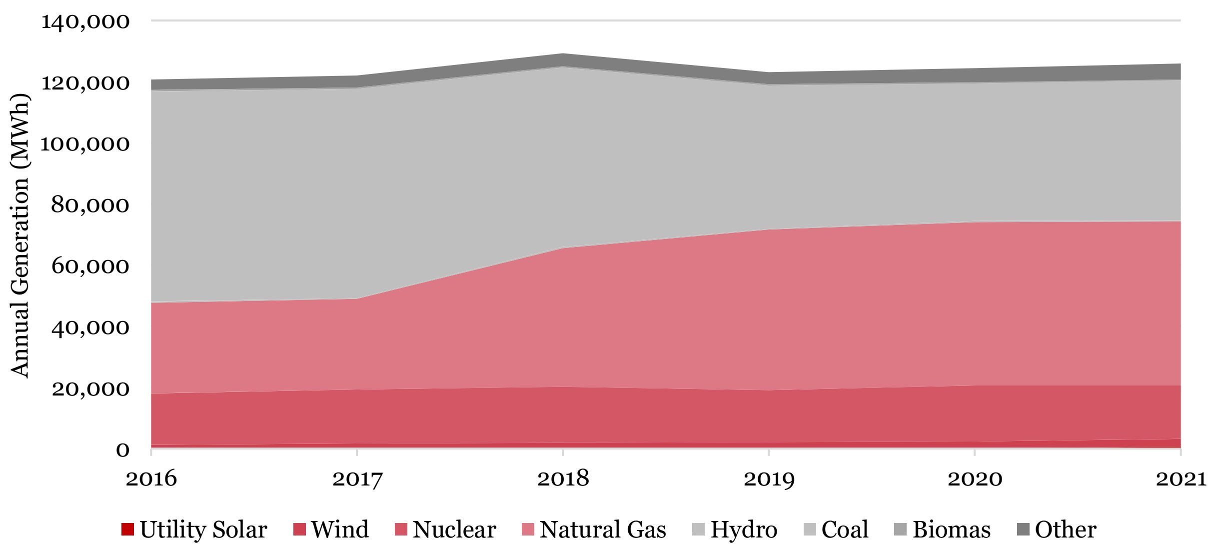
[91] Kevin Rennert et al., "**Comprehensive evidence implies a higher social cost of CO_2**," Nature, 610, (September 2022) p. 687–692.

[92] **Regulatory Impact Analysis for the Clean Power Plan Final Rule**, U.S. Environmental Protection Agency, October 23, 2015.

benefit/cost ratio. The benefit value is based on the amount of CO_2 avoided by replacing fossil fuels with renewable source power. We combine this amount of avoided CO_2 with various values of the social cost of carbon to derive a "benefit" value. Because The Buckeye Institute does not have access to all the modeling tools the EPA utilized in the CPP's RIA, we present simplified calculations and make simplifying assumptions for which we will provide any necessary context.

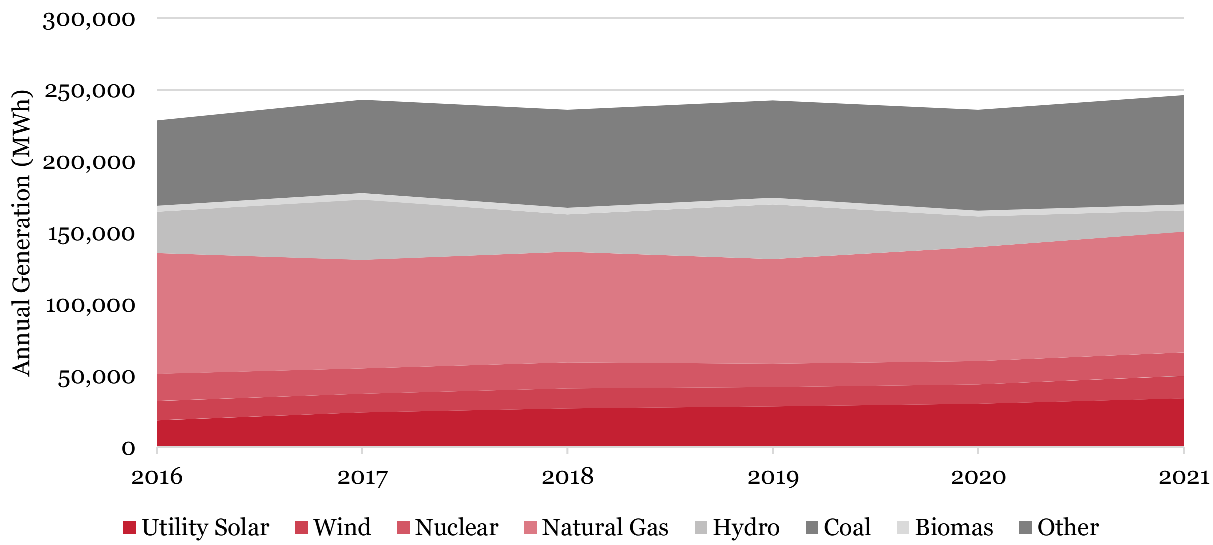
The first data set presents the amount of power generated by technology by each state.[93]

Figure 3.1: Ohio Electricity Generation by Technology



93 Energy Information Administration, **Ohio Electricity Profile 2020**, and **California Electricity Profile 2020** (Last accessed November 7, 2022).

Figure 3.2: California Electricity Generation by Technology



Tables 3.1 and 3.2 provide the raw data of existing sources of electric power in Ohio and California. Tables 3.3 and 3.4 convert the data from Tables 3.1 and 3.2 into percentages. From 2016 to 2021, California's renewable usage climbs from 48.8 percent in 2016 to 52.6 percent in 2021. Ohio's renewable usage was 2.9 percent in 2016 and 5.6 percent in 2021. The shift in generation mix can be observed in Figures 3.1 and 3.2 for Ohio and California, respectively.

Table 3.1: Ohio Energy Generation by Source (MWh)

	2016	2017	2018	2019	2020	2021
Utility Based Solar	61	100	114	136	160	649
Wind	1,191	1,530	1,684	1,967	2,207	2,500
Petroleum Liquids	212	203	214	160	115	126
Petroleum Coke	955	1,035	1,087	676	1057	842
Other	-60	-11	-7	-5	-6	0
Other Renewables	1,714	2,112	2,283	2,554	2,799	3,560
Other Gasses	553	623	630	631	576	541
Nuclear	16,817	17,688	18,315	17,011	18,219	17,483
Natural Gas	29,591	29,654	45,517	52,424	53,424	53,635
Hydro Pumped Storage	0	0	0	0	0	0
Geothermal	0	0	0	0	0	0
Conventional Hydro	500	277	244	403	375	357
Coal	68,662	68,334	58,721	46,762	45,008	45,766
Biomass	463	483	484	452	432	412
Total	**120,659**	**122,028**	**129,286**	**123,171**	**124,366**	**125,871**

Table 3.2: California Energy Generation by Source (MWh)

	2016	2017	2018	2019	2020	2021
Utility Based Solar	18,677	24,214	26,817	28,140	30,061	33,973
Wind	13,498	12,812	14,013	13,724	13,572	15,614
Petroleum Liquids	40	38	39	41	39	42
Petroleum Coke	0	0	0	0	0	0
Other	179	200	143	150	145	54
Other Renewables	48,130	52,967	57,035	57,274	59,176	65,358
Other Gasses	0	0	0	0	0	0
Nuclear	18,908	17,901	18,214	16,165	16,259	16,477
Natural Gas	84,476	75,906	77,519	73,454	79,912	84,645
Hydro Pumped Storage	-259	407	-149	-31	-37	-317
Geothermal	11,457	11,560	11,677	10,914	11,367	11,446
Conventional Hydro	28,930	42,344	26,320	38,341	21,371	14,553
Coal	0	0	0	0	0	0
Biomass	4,498	4,381	4,527	4,495	4,177	4,326
Total	**228,534**	**242,730**	**236,155**	**242,667**	**236,042**	**246,171**

Table 3.3: Ohio Energy Source as Percentage of Total Electricity Generation (MWh)

	2016	2017	2018	2019	2020	2021
Utility Based Solar	0.051%	0.082%	0.088%	0.110%	0.129%	0.516%
Wind	0.987%	1.254%	1.303%	1.597%	1.775%	1.986%
Petroleum Liquids	0.176%	0.166%	0.166%	0.130%	0.092%	0.100%
Petroleum Coke	0.791%	0.848%	0.841%	0.549%	0.850%	0.669%
Other	-0.050%	-0.009%	-0.005%	-0.004%	-0.005%	0.000%
Other Renewables	1.421%	1.731%	1.766%	2.074%	2.251%	2.828%
Other Gasses	0.458%	0.511%	0.487%	0.512%	0.463%	0.430%
Nuclear	13.938%	14.495%	14.166%	13.811%	14.650%	13.890%
Natural Gas	24.524%	24.301%	35.206%	42.562%	42.957%	42.611%
Hydro Pumped Storage	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Geothermal	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Conventional Hydro	0.414%	0.227%	0.189%	0.327%	0.302%	0.284%
Coal	56.906%	55.999%	45.419%	37.965%	36.190%	36.359%
Biomass	0.384%	0.396%	0.374%	0.367%	0.347%	0.327%

Table 3.4: California Energy Source as Percentage of Total Electricity Generation (MWh)

	2016	2017	2018	2019	2020	2021
Utility Based Solar	8.173%	9.976%	11.356%	11.596%	12.735%	13.801%
Wind	5.906%	5.278%	5.934%	5.655%	5.750%	6.343%
Petroleum Liquids	0.018%	0.016%	0.017%	0.017%	0.017%	0.017%
Petroleum Coke	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Other	0.078%	0.082%	0.061%	0.062%	0.061%	0.022%
Other Renewables	21.060%	21.821%	24.152%	23.602%	25.070%	26.550%
Other Gasses	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Nuclear	8.274%	7.375%	7.713%	6.661%	6.888%	6.693%
Natural Gas	36.964%	31.272%	32.825%	30.269%	33.855%	34.385%
Hydro Pumped Storage	-0.113%	0.168%	-0.063%	-0.013%	-0.016%	-0.129%
Geothermal	5.013%	4.762%	4.945%	4.498%	4.816%	4.650%
Conventional Hydro	12.659%	17.445%	11.145%	15.800%	9.054%	5.912%
Coal	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Biomass	1.968%	1.805%	1.917%	1.852%	1.770%	1.757%

Ohio and California are net importers of power. California imports 30 percent[94] and Ohio imports between 20 and 25 percent from nearby states.[95] Additionally, Ohio's temperate climate and limited exposure to the sun reduces the efficiency of utility solar.[96] Consequently, Ohio will need to rely heavily on wind, or build out a commensurate amount of utility solar to offset the efficiency losses. The actual renewable build out required to achieve true net-zero emissions is therefore larger than we estimate here.

The CPP established new carbon emission goals for each state and existing sources of air pollution—mostly coal-fired power plants. These goals were designed to reduce emissions by a larger percentage in states that had less renewable energy

94 **2021 Total System Electric Generation**, California Energy Commission (Last visited December 1, 2022).

95 **Ohio State Profile and Energy Estimates**, U.S. Energy Information Administration, August 18, 2022.

96 **Ohio Sunlight Hours & Renewable Energy Information**, TurbineGenerator.org (Last Visited, December 19, 2022).

sources. Table 3.5 presents data from the CPP's RIA showing mass-based goals for Ohio and California.[97]

Table 3.5: Clean Power Plan Emission Reduction Targets[98]

State	Interim Goal Ton CO_2/yr	Final Goal Ton CO_2/yr
California	51,027,075	48,410,120
Ohio	82,526,513	73,769,806

As time passes, each state will inevitably change its generation capacity as old power plants are retired and replaced. The type of power plant a state builds depends heavily on existing state and federal emissions regulations. We assume therefore that the percent change between interim and final goal times two represents the desired change over 15 years. California will be required to lower CO_2 emissions by 10.8 percent and Ohio by 23.7 percent under the new CPP. California's emission reduction burden is less than Ohio's because California has completed a robust build out of renewable power infrastructure. Nevertheless, to meet its emissions goal, California will have to shut down natural gas power plants as the annual emissions from its four remaining coal plants are less than the reduction requirement.

Next, we updated the production forecast for Ohio and California. Using information from EIA,[99] California Independent System Operator (CAISO),[100] PJM,[101] and the results above, Figure 3 shows the forecast power to 2035.

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[97] **Regulatory Impact Analysis for the Clean Power Plan Final Rule**, U.S. Environmental Protection Agency, October 23, 2015.
[98] Table 3.1; *Ibid.*
[99] **Electricity Data Browser**, U.S. Energy Information Administration (Last visited November 28, 2022).
[100] **Renewables and emissions reports**, California Independent System Operator (Last visited November 28, 2022).
[101] **Data Directory**, PJM (Last visited November 28, 2022).

Figure 3.3: Power Forecast

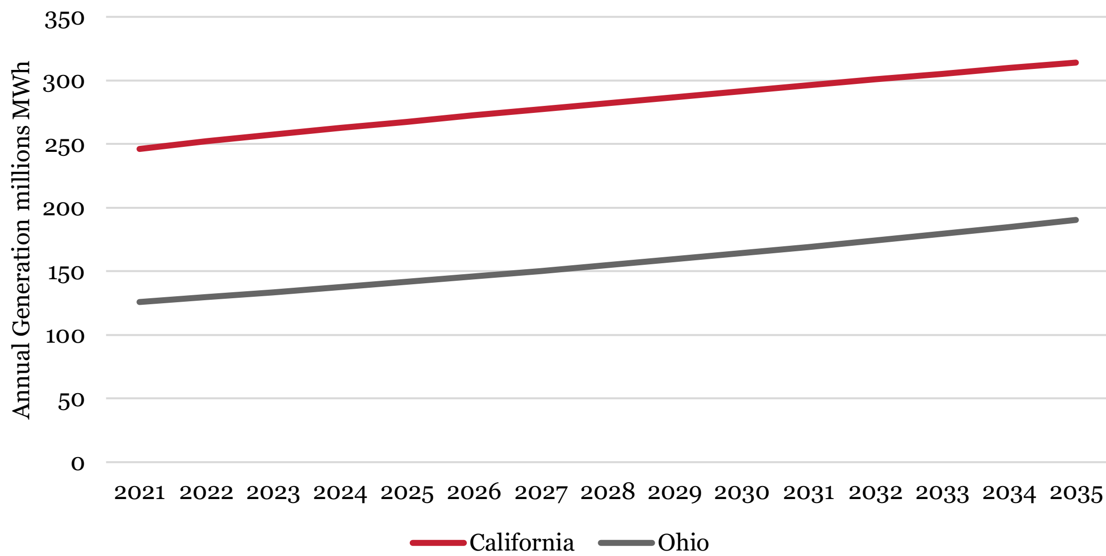


Table 3.6: Existing Emissions 2021[102]

State	Coal emissions (ton CO_2/year	Natural Gas emissions (ton CO_2/year	Total emissions (ton CO_2/year)
California	351,109	55,076,744	55,427,853
Ohio	54,656,025	30,912,386	85,568,412

The estimated CO_2 emissions in 2021 for each state are calculated by using the generation by type values from above and applying factors from the CPP RIA.[103] Table 3.6 presents the type values for coal and natural gas.

[102] Calculated using factors from Table 2.7; *Ibid.*
[103] Table 2-7: **Regulatory Impact Analysis for the Clean Power Plan Final Rule**, U.S. Environmental Protection Agency, October 23, 2015.

Table 3.7: New Clean Power Plan Goals[104]

State	Interim Goal Ton CO_2/yr	Final Goal Ton CO_2/yr
California	52,431,534	49,435,213
Ohio	75,411,173	65,253,935

Based on these values and the percent changes, we calculated a new set of CO_2 emissions goals for a new CPP (Table 3.7).

This analysis assumes that wind and solar power meet all future demand growth for energy. This assumption is based on the use of a mass and not percent-based cap on CO_2 emissions. The mass-based cap sets a hard ceiling on the amount of CO_2 emissions independent of the total amount of power generated. We also assume all the generation needed to reduce emissions is the replacement of coal- and natural gas-fired electricity generating units (EGUs) with wind and solar EGUs.

Figure 3.4 shows the projected baseline and CPP-controlled emissions of CO_2 for Ohio and California.

[104] Calculated using factors from Table 2.7; *Ibid.*

Figure 3.4: CO_2 Emissions under New CPP (tons CO_2/year)

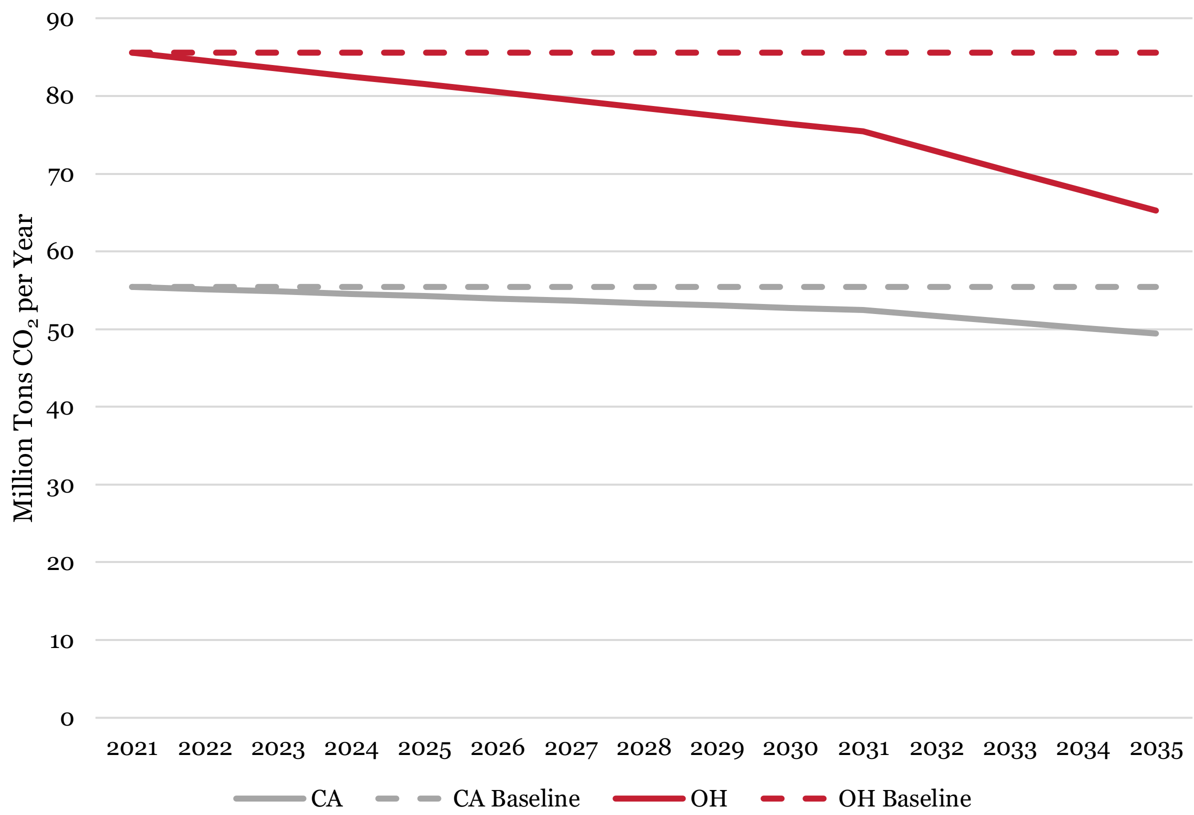


Figure 3.4 and the Figure 3.3 are used to determine the necessary amount of wind and solar power. Knowing the amount of power needed allows us to calculate the number of "units" of wind (2MW turbine) and solar (1km2 area) energy (Figure 3.5).

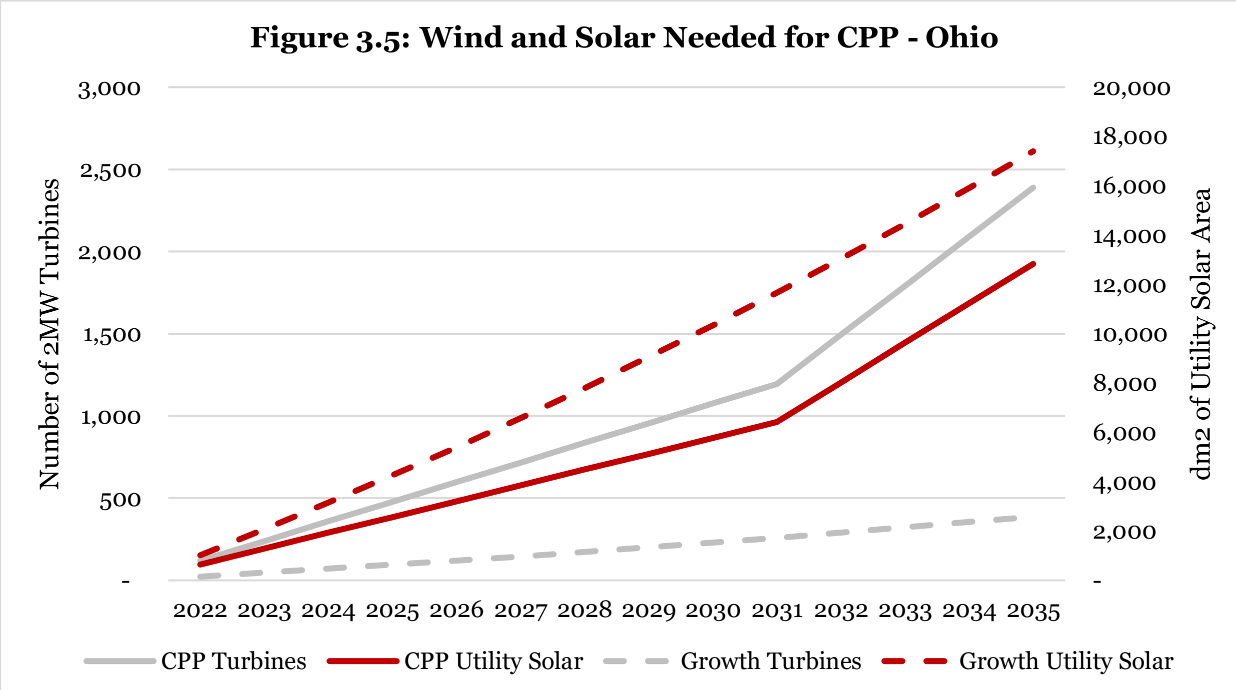


Figure 3.5: Wind and Solar Needed for CPP - Ohio
Number of 2MW Turbines
3,000
2,500
2,000
1,500
1,000
500
-
dm2 of Utility Solar Area
20,000
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
-
2022 2023 2024 2025 2026 2027 2028 2029 2030 2031 2032 2033 2034 2035
CPP Turbines
CPP Utility Solar
Growth Turbines
Growth Utility Solar

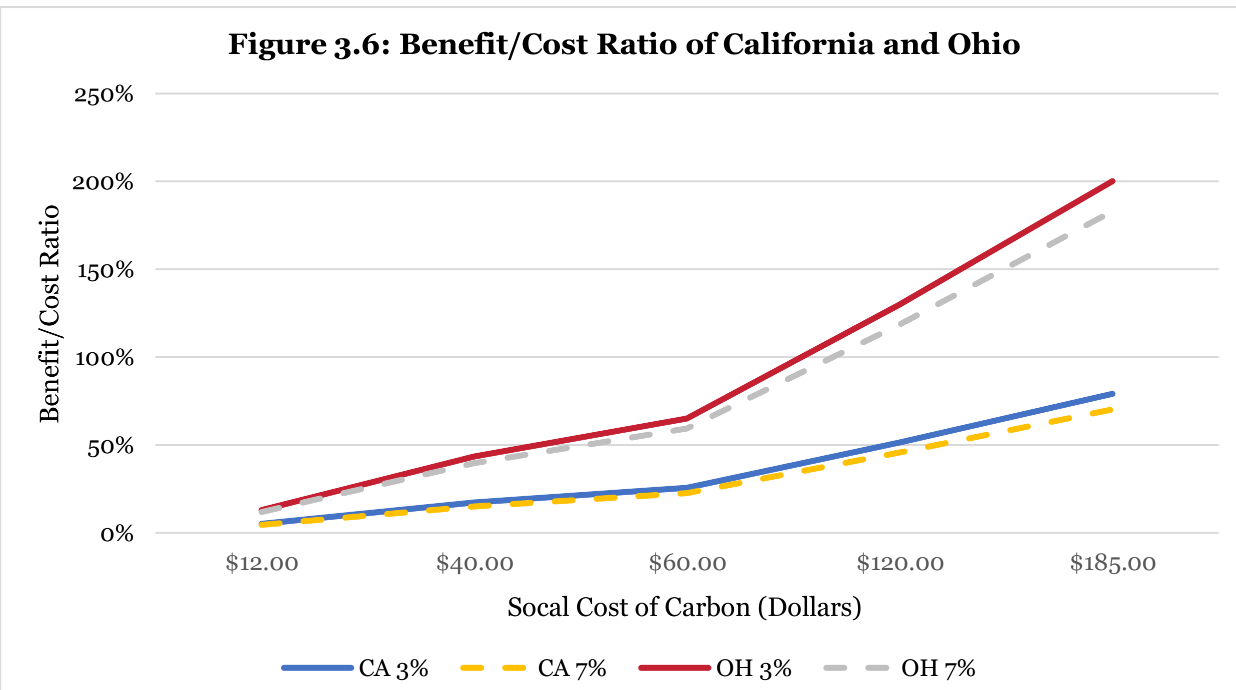
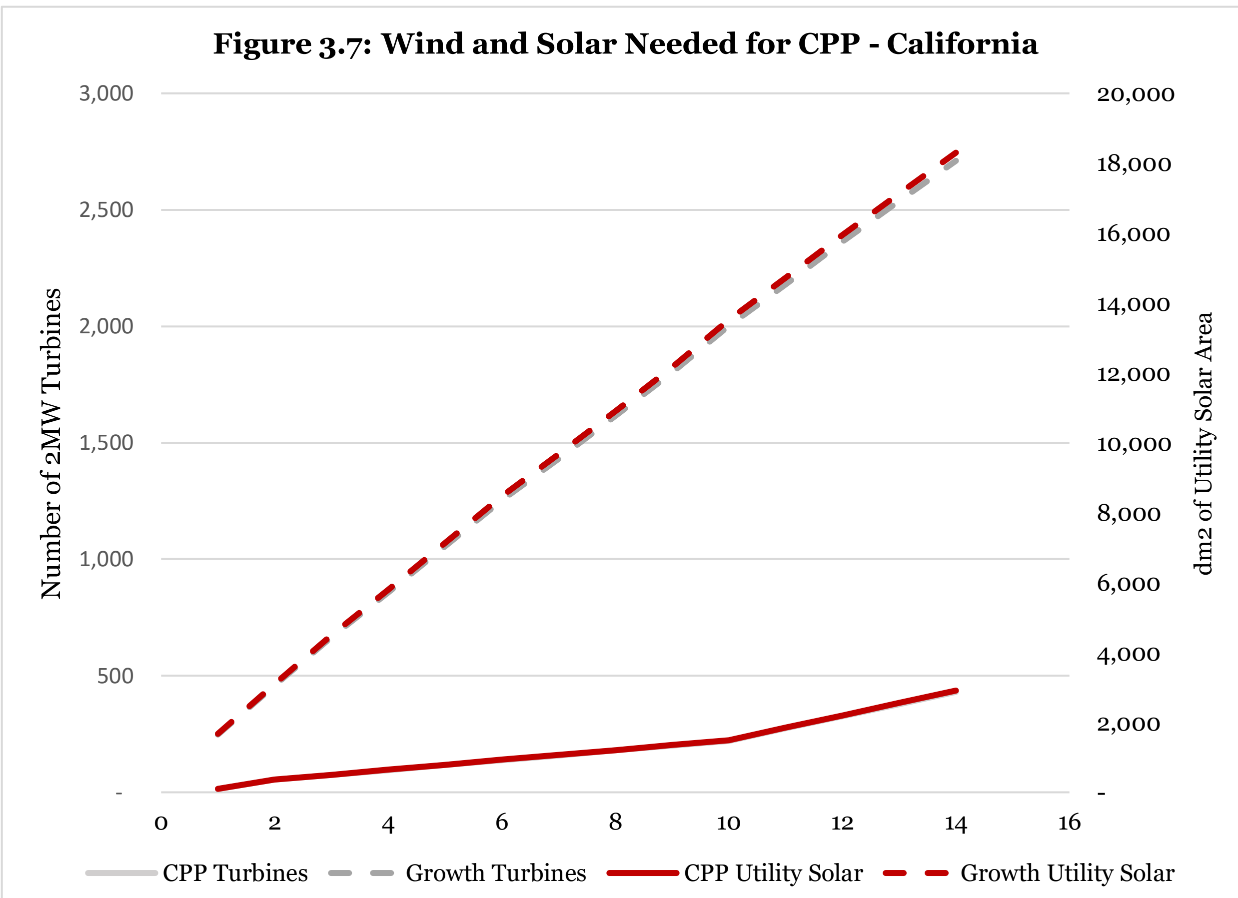


Figure 3.6: Benefit/Cost Ratio of California and Ohio
Benefit/Cost Ratio
250%
200%
150%
100%
50%
0%
$12.00
$40.00
$60.00
$120.00
$185.00
Socal Cost of Carbon (Dollars)
CA 3%
CA 7%
OH 3%
OH 7%

Figure 3.6 charts the benefit cost ratio at the five estimates of the social cost of carbon. Scenarios below the 100 percent threshold do not justify increasing renewable buildout. Ohio only passes the benefit cost analysis when the SCC exceeds approximately $100. Given the current SCCs, California does meet the benefit threshold to justify building out additional renewable generation capacity. California already generates a significant amount of electricity from renewable power sources. To meet the decarbonization requirements set by the new CPP, California will need to replace existing natural gas power plants with zero emissions sources of electricity. Figure 3.7 shows how many wind turbines and solar panels will be needed to meet the new CPP requirement. In addition to replacing generation capacity with zero-emission sources, California will also need to build out more renewables to meet growing demand for power.



We calculate capital and operating costs of the wind and solar additions using the NREL report[105] and the amount power generated to displace CO_2. We use the methodology from a paper by Will Gorman, Andrew Mills, and Ryan Wiser.[106] The capital cost of additional transmission to accommodate the added renewable power is included in the calculation.

The benefit/cost ratio is calculated using the number of wind and solar units and the amount of obviated CO_2 emissions. Tables 3.9 and 3.10 contain the data generated from several scenarios used to produce Figure 3.7. These scenarios used five different values for the SSC and the OMB prescribed discount rates to calculate NPV. When the benefit/cost ratio exceeds one, building out renewable sources of power would create a future benefit.

Table 3.8: Emission Reduction Benefit Monetized: Ohio

	Cost	$12.00	$40.00	$60.00	$120.00	$185.00
Discount Rate 3%	$8,331,631,000	$1,081,724,000	$3,605,748,000	$5,408,622,000	$10,817,245,000	$16,676,586,000
Benefit Cost Ratio		0.13	0.43	0.65	1.30	2.00
Discount Rate 7%	$6,118,445,000	$726,401,000	$2,421,336,000	$3,632,004,000	$7,264,008,000	$11,198,679,000
Benefit Cost Ratio		0.12	0.40	0.59	1.19	1.83

[105] **Annual Technology Baseline 2021**, National Renewable Energy Laboratory (Last visited November 28, 2022)

[106] Will Gorman, Andrew Mills, and Ryan Wiser, "**Improving estimates of transmission capital costs for utility-scale wind and solar projects to inform renewable energy policy**," *Energy Policy*, Volume 135 (December 2019)

Table 3.9: Emission Reduction Benefit Monetized: California

	Cost	$12.00	$40.00	$60.00	$120.00	$185.00
Discount Rate 3%	$6,216,792,000	$319,102,000	$1,063,672,000	$1,595,509,000	$3,191,017,000	$4,919,485,000
Benefit Cost Ratio		0.05	0.17	0.26	0.51	0.79
Discount Rate 7%	$4,702,579,000	$214,284,000	$714,278,000	$1,071,418,000	$2,142,835,000	$3,303,538,000
Benefit Cost Ratio		0.05	0.15	0.23	0.46	0.70

Additionally, Tables 3.8 and 3.9 demonstrate how the SSC and discount rate tilt results. At a three and seven percent discount rate and a SCC of $120 and $185/ton CO_2 SSC, Ohio passes the cost benefit test. California does not pass the cost benefit test at any discount rate or any social cost of carbon. Although Ohio passes the BCA, these calculations did not account for differences in efficiency between renewable sources of energy built in California versus Ohio.

Based on values from CPP's RIA, California is expected to reduce CO_2 emissions by five percent by 2028, and 10 percent by 2035. The corresponding values for Ohio are 12 percent and 24 percent. The CPP assigned greater reduction goals to states with larger emissions.

Estimated CO_2 emissions from the California electricity sector is 55,427,000 tons/year in 2021. Reduction by 10 percent means a reduction of 5,543,000 tons/year, which implies that all coal facilities (294,000 MWh) and natural gas facilities would be reduced by ~9.5 percent (9,095,000 MWh). California electricity consumption is expected to grow by 27.5 percent from 2021 to 2035, which implies a total annual demand for new renewable power of about 78.3 million MWh.

California only has four remaining coal plants and replacing them all with zero-emission renewables would not meet the emissions reduction target set by the new CPP. To meet this goal, California will have to replace existing natural gas plants with the most economically viable zero-emission source of power. Currently, wind is the cheapest zero-emissions source of energy California could use. Assuming a name plate capacity of 2MW for a wind turbine and a 45 percent capacity factor, California will need approximately 9,900 additional turbines to meet the needed grid capacity without imports. The overnight capital cost for the turbines is $29 billion.[107] In addition to the financing and overnight costs, California utilities will need to expand existing grid infrastructure capable of harnessing and transmitting the additional wind power. Based on capital costs and the number of households, when fully implemented, Californians will see their electric bills rise approximately $2,200 over 15 years.

This pure wind play does not include expanding solar or other zero-emission EGUs. Although this scenario is not practical from an energy security perspective, it demonstrates the high cost of zero-emissions legislation.

[107] **Annual Technology Baseline 2021**, National Renewable Energy Laboratory (Last visited November 28, 2022).

Economic Impacts on Ohio and California of Shifting from Fossil Fuel to Renewable Energy

The ERC uses a dynamic scoring model to forecast the impact of state-level tax policy changes on government revenues, economic activity, job creation, and business investment. We use publicly available state and federal data to calibrate that model to economic performance in Ohio and California. Appendix A provides the details of the model's equations and input parameters.

Applying the ERC model, we forecast the economic impact of a new Clean Power Plan under four scenarios—two for California and two for Ohio using the OMB's prescribed real discount rates of three percent and seven percent.[108] The discount rates reflect the inherent differences in the way capital is valued with preference to time. The three percent discount rate is the social rate of time preference and reflects the rate at which the "average saver" discounts their future consumption.[109] The seven percent discount rate is the average, pre-tax return on private capital. This rate reflects the return-on-investment corporations, small businesses, and property earners can expect to accrue.[110] The higher the discount rate, the more present consumption that is forfeited. By discounting at three percent and seven percent, our models indicate how much present economic activity will be removed from the California and Ohio economies in order to meet the requirements of a revived Clean Power Plan.

[108] OMB Circular A-4, **Regulatory Impact Analysis**, September 17, 2003.
[109] *Ibid.*
[110] *Ibid.*

Scenario 1: Impact of New Clean Power Plan on Ohio at a Seven Percent Discount Rate

CPP Ohio 7% Discount Rate
($6.12B NPV Cost Half Income, Half Corporate)[111]

	Baseline				
Year	GDP	Employment	Tax Revenue	Consumption	Investment
2023	$730,979	5,618	$31,766	$501,577	$170,333
2024	$741,348	5,708	$31,196	$512,225	$173,679
2025	$747,697	5,739	$31,486	$520,164	$173,976
2026	$753,827	5,760	$31,775	$527,518	$1,758,848
2027	$759,477	5,779	$32,061	$534,121	$178,384
2028	$765,962	5,794	$32,347	$542,308	$181,484
2029	$772,897	5,811	$32,632	$551,897	$184,381
2030	$780,126	5,794	$32,917	$561,781	$187,815
2031	$787,380	5,811	$33,207	$571,814	$191,310
2032	$794,625	5,840	$33,503	$582,106	$194,641
	Difference from Baseline				
Year	GDP	Employment	Tax Revenue	Consumption	Investment
2023	$0	0	$0	$0	$0
2024	-$440	-1	-$360	-$70	-$280
2025	-$860	-3	-$700	-$150	-$550
2026	-$1,260	-4	-$1,020	-$210	-$800
2027	-$1,630	-5	-$1,310	-$280	-$1,040
2028	-$1,980	-6	-$1,590	-$340	-$1,250
2029	-$2,310	-7	-$1,840	-$400	-$1,460
2030	-$2,620	-8	-$2,080	-$450	-$1,650
2031	-$2,920	-9	-$2,310	-$500	-$1,820
2032	-$3,190	-10	-$2,510	-$550	-$1,990

[111] Source: The Economic Research Center's dynamic scoring model. Note: GDP, tax revenues, consumption and investment in millions of 2021 dollars. Employment is full-time equivalent non-farm jobs, in thousands of jobs. Difference from Baseline results are rounded to the nearest $10 million for GDP, tax revenue, consumption and investment and are rounded to the nearest thousand for employment.

Using OMB's prescribed seven percent discount rate, by 2032, Ohio's GDP will fall by $3,190 billion. Rising utility bills will force businesses to adopt austere conditions. Ohio's economy will be short 10,000 jobs. Private investment and consumption will decline by $1.99 billion and $550 million, respectively. In addition to the private sector damage, the public sector will suffer a significant revenue shortfall, with a $3.390 billion revenue decline.

Scenario 2: Impact of New Clean Power Plan on Ohio at a Three Percent Discount Rate

CPP Ohio 3% Discount Rate
($8.33B NPV Cost Half Income, Half Corporate)[112]

	Baseline				
Year	GDP	Employment	Tax Revenue	Consumption	Investment
2023	$730,979	5,618	$31,766	$501,577	$170,333
2024	$741,348	5,708	$31,196	$512,225	$173,679
2025	$747,697	5,739	$31,486	$520,164	$173,976
2026	$753,827	5,760	$31,775	$527,518	$1,758,848
2027	$759,477	5,779	$32,061	$534,121	$178,384
2028	$765,962	5,794	$32,347	$542,308	$181,484
2029	$772,897	5,811	$32,632	$551,897	$184,381
2030	$780,126	5,794	$32,917	$561,781	$187,815
2031	$787,380	5,811	$33,207	$571,814	$191,310
2032	$794,625	5,840	$33,503	$582,106	$194,641
	Difference from Baseline				
Year	GDP	Employment	Tax Revenue	Consumption	Investment
2023	$0	0	$0	$0	$0
2024	-$600	-2	-$490	-$100	-$390
2025	-$1,170	-4	-$950	-$200	-$750
2026	-$1,710	-5	-$1,380	-$290	-$1,090
2027	-$2,220	-7	-$1,780	-$380	-$1,410
2028	-$2,700	-8	-$2,150	-$460	-$1,700
2029	-$3,150	-10	-$2,490	-$540	-$1,980
2030	-$3,570	-11	-$2,810	-$620	-$2,230
2031	-$3,970	-13	-$3,110	-$690	-$2,480
2032	-$4,340	-14	-$3,380	-$750	-$2,700

[112] Source: The Economic Research Center's dynamic scoring model. Note: GDP, tax revenues, consumption and investment in millions of 2021 dollars. Employment is full-time equivalent non-farm jobs, in thousands of jobs. Difference from Baseline results are rounded to the nearest $10 million for GDP, tax revenue, consumption and investment and are rounded to the nearest thousand for employment.

Under a second scenario, capital is discounted at a three percent rate. The modelled results reveal the economic shock of higher utility bills rippling through the economy and show twice the economic damage of the three percent discount rate. The full cost of the new CPP is felt in 2032. Rising utility prices will destroy 14,000 jobs. Consumption and investment will fall by $2.7 billion and $750 million, respectively. Tax revenue will decline by $3.38 billion. The decrease in economic activity will inflict a $4.34 billion dollar drop in real GPD.

Scenario 3: Impact of New Clean Power Plan on California at a Seven Percent Discount Rate

CPP California 7% Discount Rate
($4.702B NPV Cost Half Income, Half Corporate)[113]

	Baseline				
Year	GDP	Employment	Tax Revenue	Consumption	Investment
2023	$3,605,629	18,678	$93,865	$1,984,362	$717,812
2024	$3,751,449	18,977	$96,780	$2,037,287	$732,605
2025	$3,829,315	19,081	$104,893	$2,073,132	$728,720
2026	$3,904,366	19,152	$106,882	$2,106,036	$735,180
2027	$3,972,654	19,212	$108,626	$2,135,151	$745,879
2028	$4,054,464	19,264	$110,196	$2,172,216	$760,103
2029	$4,144,156	19,321	$112,114	$2,216,359	$773,111
2030	$4,239,523	19,416	$114,381	$2,262,019	$789,467
2031	$4,336,401	19,505	$116,723	$2,308,469	$806,256
2032	$4,434,241	19,601	$119,130	$2,356,267	$822,077
	Difference from Baseline				
Year	GDP	Employment	Tax Revenue	Consumption	Investment
2023	$0	0	$0	$0	$0
2024	-$860	-2	-$310	-$320	-$540
2025	-$1,640	-3	-$580	-$600	-$1,040
2026	-$2,310	-4	-$830	-$850	-$1,440
2027	-$2,880	-5	-$1,050	-$1,060	-$1,780
2028	-$3,420	-6	-$1,250	-$1,250	-$2,100
2029	-$3,920	-7	-$1,440	-$1,440	-$2,400
2030	-$4,340	-8	-$1,590	-$1,590	-$2,650
2031	-$4,740	-9	-$1,740	-$1,730	-$2,880
2032	-$5,110	-10	-$1,870	-$1,870	-$3,100

[113] Source: The Economic Research Center's dynamic scoring model. Note: GDP, tax revenues, consumption and investment in millions of 2021 dollars. Employment is full-time equivalent non-farm jobs, in thousands of jobs. Difference from Baseline results are rounded to the nearest $10 million for GDP, tax revenue, consumption and investment and are rounded to the nearest thousand for employment.

Scenario three applies the ERC model calibrated at a seven percent discount rate to California. The full weight of a new Clean Power Plan will be felt in 2032 when $5.11 billion will be extirpated from California's economy. This precipitous decline in GDP will be fed by a $3.1 billion drop in private investment and $1.87 billion decline in consumption. California's employers will retract 13,000 jobs. As a result of declining economic activity, the state's public sector will see a tax revenue shortfall of $1.87 billion.

Scenario 4: Impact of New Clean Power Plan on California at a Three Percent Discount Rate

CPP California 3% Discount Rate
($6.217B NPV Cost Half Income, Half Corporate)[114]

	Baseline				
Year	GDP	Employment	Tax Revenue	Consumption	Investment
2023	$3,605,629	18,678	$93,865	$1,984,362	$717,812
2024	$3,751,449	18,977	$96,780	$2,037,287	$732,605
2025	$3,829,315	19,081	$104,893	$2,073,132	$728,720
2026	$3,904,366	19,152	$106,882	$2,106,036	$735,180
2027	$3,972,654	19,212	$108,626	$2,135,151	$745,879
2028	$4,054,464	19,264	$110,196	$2,172,216	$760,103
2029	$4,144,156	19,321	$112,114	$2,216,359	$773,111
2030	$4,239,523	19,416	$114,381	$2,262,019	$789,467
2031	$4,336,401	19,505	$116,723	$2,308,469	$806,256
2032	$4,434,241	19,601	$119,130	$2,356,267	$822,077
	Difference from Baseline				
Year	GDP	Employment	Tax Revenue	Consumption	Investment
2023	$0	0	$0	$0	$0
2024	-$1,140	-2	-$380	-$420	-$730
2025	-$2,200	-4	-$730	-$810	-$1,380
2026	-$3,090	-6	-$1,040	-$1,130	-$1,920
2027	-$3,850	-7	-$1,310	-$1,410	-$2,380
2028	-$4,570	-8	-$1,560	-$1,670	-$2,810
2029	-$5,240	-10	-$1,790	-$1,920	-$3,210
2030	-$5,800	-11	-$1,980	-$2,120	-$3,530
2031	-$6,330	-12	-$2,170	-$2,320	-$3,850
2032	-$6,840	-13	-$2,340	-$2,500	-$4,140

[114] Source: The Economic Research Center's dynamic scoring model. Note: GDP, tax revenues, consumption and investment in millions of 2021 dollars. Employment is full-time equivalent non-farm jobs, in thousands of jobs. Difference from Baseline results are rounded to the nearest $10 million for GDP, tax revenue, consumption and investment and are rounded to the nearest thousand for employment.

Scenario four models the impact of the new CPP on California's economy at the three percent discount rate. In 2032, private consumption and investment in California will sink $2.5 and $4.14 billion, respectively, below the baseline. California's job market will shrink by 13,000 jobs. As a direct result of declining economic activity, tax revenue will precipitously decline by $2.34 billion. In total, lingering economic malaise created by the new CPP will cause California's GDP to decline by $6.840 billion.

Financial Impacts on Californians and Ohioans

On April 22, 2021, President Biden set 2035 as the target year for a carbon pollution-free power sector.[115] This goal will require all future growth in power generation to use zero-emission energy sources and to replace existing coal- and natural gas-fired power plants with wind and solar energy. But because the Biden Administration merely announced a target, it did not need to provide a Regulatory Impact Analysis (RIA) modeling the policy's cost, benefits, or economic impact. California and Ohio's inherent geographic, demographic, and energy differences make them ideal for assessing the disparate impact that emission reduction goals can have on different electric power markets and the financial costs passed onto people.

California's geography is well-suited for renewable power generation. Additionally, a 2015 executive order from then-Governor Brown and Senate Bill 32 and Senate Bill 100 in 2016 and 2018, respectively, spurred California's renewable power buildout,[116] which give the state a running start in meeting President Biden's 2035 emissions target.

The capital costs of meeting future power demand and replacing fossil fuel plants with wind and solar energy in California depend on which discount rate is used. Using a seven percent discount rate, California will spend $4.7 billion; but a three percent discount rate indicates the transition will cost $6.2 billion.[117] Spreading these capital costs evenly across California's 13.2 million households yields a onetime per household cost of $350 - $460, or approximately a half a percent of

[115] White House, **FACT SHEET: President Biden Sets 2030 Greenhouse Gas Pollution Reduction Target Aimed at Creating Good-Paying Union Jobs and Securing U.S. Leadership on Clean Energy Technologies**, April 22, 2021.
[116] Office of Governor, **Governor Brown Establishes Most Ambitious Greenhouse Gas Reduction Target in North America**, 29 April, 2015; Environmental Defense Fund, **California leads fight to curb climate change**; **California Energy Commission, SB 100 Joint Agency Report**, March 2021.
[117] Table 9.

the median household's $85,000 per year income.[118] Although the per household cost is low and may appear "worth it" for some environmentally conscious residents, these small per household charges do not accurately reflect the full price for clean energy in California.

The overnight costs of meeting the Biden Administration's emissions target ranges from $69.29 - $91.61 per megawatt-hour (MWh). These overnight costs will increase power prices by 7 - 9 cents per kilowatt-hour (KWh). As of February 2023, Californians paid an average of 29 cents per KWh.[119] The average California household consumes 9,500 KWhs per year. The extra pennies for electricity each month add up to a shocking $665 - $855 per year.

[118] U.S. Census Bureau, **Population Estimates, July 1, 2022 (V2022)** (Last accessed March 30, 2023).

[119] U.S. Bureau of Labor Statistics, **Average Energy Prices, Los Angeles-Long Beach-Anaheim – December 2022**, January 18, 2023; and **Average Energy Prices, San Francisco-Oakland-Hayward – February 2023**, March 16, 2023 (Last accessed March 30, 2023)

Table 3.10: California[120]

	Riley	Maria	Jane	Raul	Skyler
Gross Income	$24,990	$30,000	$46,000	$55,000	$67,000
City of Residence	Compton	Riverside	Los Angeles	Napa	San Diego
Current Yearly Electricity Expense (EE)	$1,800	$3,260	$1,800	$2,320	$1,890
Emission Reduction Plan EE	$2,230	$4,040	$2,230	$2,870	$2,350
Zero-Emission Energy Premium	$430	$780	$430	$550	$460
% of Income Spent on Electricity	7.20%	10.90%	3.90%	4.20%	2.80%
% of Income Spent on Reduced-Emission Electricity	8.90%	13.50%	4.80%	5.20%	3.50%
Marital Status	Single	Single	Single	Single	Divorced
Earners	1	1	1	1	1
Dependents	No Kids	No Kids	1 Ailing Parent	No Kids	2 Kids

[120] Increased power costs were estimated using the per Kilowatt-hour cost increase derived from the capital expenditure costs of wind and solar power sources at a seven percent discount rate presented in Tables 3.8 and 3.9. Residential power consumption data was sourced from the California Energy Commission (2021). Residential Power consumption was scaled by two percent growth factor to estimate consumption in 2022. Housing Data was sourced form State of California Department of Finance E-5 Population and Housing Estimates for Cities, Counties, and the State (2020 - 2022).

Table 3.11: California[121]

	Amir and Abbey	Saul and Quin	Martín and Aurora	Kevin and Mary	Dov and Kimmy
Gross Income	$78,000	$94,000	$185,000	$450,000	$10,000,000
City of Residence	Santa Clara	San Francisco	Bakersfield	Markleeville	Bel-air
Current Yearly Electricity Expense (EE)	$1,910	$1,250	$2,820	$6,200	$1,800
Emission Reduction Plan EE	$2,370	$1,550	$3,500	$7,700	$2,230
Zero-Emission Energy Premium	$460	$300	$680	$1,500	$430
% of Income Spent on Electricity	2.40%	1.30%	1.50%	1.40%	0.00%
% of Income Spent on Reduced-Emission Electricity	3.00%	1.60%	1.90%	1.70%	0.00%
Marital Status	Married	Married	Married	Married	Married
Earners	Retired	2	2	Retired	2
Dependents	1 kid	2 Kids	3 Kids	2 Kids	1 Kid

[121] Increased power costs were estimated using the per Kilowatt-hour cost increase derived from the capital expenditure costs of wind and solar power sources at a seven percent discount rate presented in Tables 3.8 and 3.9. Residential power consumption data was sourced from the California Energy Commission (2021). Residential Power consumption was scaled by two percent growth factor to estimate consumption in 2022. Housing Data was sourced form State of California Department of Finance E-5 Population and Housing Estimates for Cities, Counties, and the State (2020 - 2022).

Rising electricity rates act much like a regressive tax. To meet the Administration's target, California's poorest households will pay a greater portion of their monthly income than wealthier Californians, which will ultimately require them to make significant financial tradeoffs that their wealthier neighbors will not have to make. (See Table 3.10.) Higher electric bills reduce discretionary funds, and for Californians making under $40,000 per year that may mean choosing between keeping the lights on and educational resources for their children.[122]

For Ohio, the price of the Biden Administration's emissions target looks even worse. Unlike California, Ohio still generates a third of its power with coal-fired plants and its geography is not nearly as conducive to renewable energy generation, which will make hitting the 2035 carbon-free power target very expensive for Ohio. Capital costs for wind and solar energy range from $6.1 billion when discounting capital at a seven percent rate to $8.3 billion when applying a three percent rate. The nominal share of the capital costs borne by Ohio's 4.7 million households[123] is a single lump sum ranging from $1,280 - $1,750. The overnight cost of the zero-emission goal likely falls between $95 – $130 per MWh – or 9 – 13 cents per KWh. Just like in California, each Ohio household will pay much more than the advertised price. (See Table 3.11.) In the worst case scenario, to meet the president's goal, every Ohioan can expect their annual electricity bills to increase by $810 - $1,170, nearly doubling what most currently pay, which would otherwise buy 3 months of groceries, pay 3 months of rent, or add nine month's contribution to retirement savings.[124] And Ohio retirees, those living on fixed income, and disabled individuals cannot simply work more hours to offset higher electric bills—they will be forced to choose between electricity and buying something else.

[122] U.S. Bureau of Labor Statistics, **California: Qunitiles of income before taxes, 2019 – 2022**, Consumer Expenditure Survey.
[123] U.S. Census Bureau, **Population Estimates, July 1, 2022 (V2022)** (Last accessed March 30, 2023).
[124] U.S. Bureau of Labor Statistics, **Midwestern region by income before taxes: Average annual expenditures and characteristic**, Consumer Expenditure Survey, 2018 – 2019.

Table 3.12: Ohio[125]

	Ross	Jane	Mike	Lance and Greta	Beth	William and Mary	Sam and Sarah	Adam and Evelyn
Gross Income	$18,900	$20,000	$32,000	$43,524	$48,000	$62,626	$175,500	$300,000
City of Residence	Youngstown	Marietta	Columbus	Columbus	Cincinnati	Zanesville	Dublin	New Albany
Current Yearly Electricity Expense (EE)	$1,110	$1,250	$1,250	$1,250	$1,080	$1,250	$1,250	$1,250
Yearly Emission Reduction Plan EE	$2,057	$2,057	$2,057	$2,057	$2,057	$2,057	$2,057	$2,057
Zero-emission premium	$947	$807	$807	$807	$977	$807	$807	$807
% of Income Spent on Electricity	5.90%	6.24%	3.90%	2.87%	2.26%	1.99%	0.71%	0.42%
% of Income Spent on Reduced-Emission Electricity	10.90%	10.30%	6.40%	4.70%	4.30%	3.30%	1.20%	0.70%
Marital Status	Single	Single	Single	Married	Widowed	Married	Married	Married
Earners	1	1	1	retired	1	1	2	retired
Dependents	No kids	No kids	1 Kid	No Kids	1 Grandchild	2 Kids	2 Kids	3 Kids

[125] Increased power costs were estimated using the per Kilowatt-hour cost increase derived from the capital expenditure costs of wind and solar power sources at a seven percent discount rate presented in Tables 3.8 and 3.9. Monthly Electricity Bills are sourced from Ohio Public Utilities Commission's Utility Rate Survey and based off of a monthly 750 KWh consumption.

Conclusion

Imposing a new Clean Power Plan on U.S. energy providers will have significant, negative economic consequences. The original CPP included flawed calculations and disregarded OMB safeguards. Those demonstrable missteps, of course, should not be repeated. Assessing the foreseeable economic impacts of a revived CPP by applying the ERC's economic model to Ohio and California reveals the true costs of trying to replace low-cost fossil-fuel energy production with high-cost, intermittent power. Those costs include lower employment, lower personal consumption, reduced investment, slowing GDPs, and lost tax revenue. Under four modelled scenarios, state GDP and tax revenues declined precipitously as the private sector responded to higher electricity prices by reducing consumption, investment, and employment. California and Ohio both fare poorly under a new CPP, and the rest of the country will not fare any better. Policymakers should look carefully at the likely economic results of imposing such a plan before moving forward with a regulatory regime dictated by agency rules and executive orders.

APPENDIX

Appendix A: The Buckeye Institute's Economic Research Center Tax Model

Economists at The Buckeye Institute's Economic Research Center have developed and maintain a dynamic scoring model to analyze how changes to tax policy impact not only government revenues but also economic output, job creation, and business investment. Unlike static models that do not account for human or market responses to policy changes, the ERC's dynamic model predicts how individuals, households, and businesses will alter their economic choices in response to changes in the private economy and public policy over time.

For this paper, the ERC calibrated the model for Ohio and California using publicly available state and federal data and relied on a similar dynamic scoring framework used by federal agencies to evaluate federal tax proposals to predict how certain policy changes will affect gross domestic product, job creation or loss, and government revenue.

The ERC's model has undergone a double-blind peer review and incorporated comments from those reviews consistent with current academic standards and methodologies. The model's full technical description provided below will allow researchers to validate the model's accuracy and the conclusions that we have drawn.

The Model Framework

The ERC's dynamic model provides a framework representing a generic state economy, with its parameters calibrated to the specific state being analyzed. It allows researchers to study the interaction of households' economic choices and firms' profit maximizing decisions with a state government that pays for its budget by taxing households and businesses. The model framework is similar to those used to study national policy, modified with some conditions tailored to the specific economic conditions of a state. Because states have more limits to trade and debt relative to a national economy, for example, the ERC's model includes a condition in which state governments satisfy a budget constraint where debt cannot increase beyond a certain level. Our model is comprised of the following three parts:

1. *The Household Problem*: Households choose how much to consume and how much to work based on their preferences and their budgets.

Households can also choose to take on debt or invest in capital used by firms. Their budgets factor in sales and excise taxes on consumption, labor income (both at the state and federal level), capital income (both at the state and federal level), and licensing. The parameters governing these taxes are estimated using state and federal data.

2. *The Firm Problem*: Firms choose labor and capital, supplied by the household, to maximize profits taking the costs of production (wages, the price of capital, and taxes) as given. Using state-level data, the model simulates production within separate sectors. The output produced is used for consumption, government expenditures, or investments in factors of production.

3. *The Government Sector*: The government sets taxes to collect revenue to pay for its expenditures; however, deficits and surpluses are allowed to a limited degree. The state's trade balance is a mathematical output of what is consumed, invested in, and government expenditures less total production in the economy.

With this framework, we then explicitly define how households and firms make their economic choices.

In the model environment, time is discrete and lasts forever. In every period the economy is populated by heterogeneous households specialized in the production of one of s types of goods. The Bureau of Economic Analysis (BEA) reports macroeconomic data for the 50 states in yearly intervals, so each period represents a year in this framework. Each sector s is populated by a large number of firms specialized in the production in their sector. The economy also features a government sector that collects taxes and purchases goods from all sectors. A share $q^e \in (0,1)$ of households has earning ability $e = \{1, \dots, E\}$. These shares are such that the total population is $\sum_{e=1}^{E} q^e = 1$. The share of households with the required skills to work in sector s is $\mu_s \in (0,1)$ such that $\sum_{s=1}^{S} \mu_s = 1$. We then outline each part of the model: the household problem, the firm problem, and the government sector.

The Household Problem

The household has preferences between consumption and leisure. These preferences are represented by a period t utility function U_t, which takes the following form:

$$U_t = \sum_{s=1}^{S} \alpha_s \ln\left(c_{e,t}(s)\right) - \chi_e l_{e,t}(s)^{\left(1+\frac{1}{\psi_e}\right)}$$

Taking the prices, taxes, and previous period $t-1$ choices as given, each period t, household e chooses: how much to consume $c_{e,t}(s)$ from each sector s; the amount of future capital stock $k_{e,t}(s)$ for each sector s; investment $x_{e,t}(s)$ for each sector s; how much to borrow in debt $d_{e,t}$; and how much to work $l_{e,t}(s)$ in each sector s. Households place a utility weight on consumption goods according to $\alpha_s \in (0,1)$ where α_s represents the share of total GDP in sector s. Period time is split between labor and leisure such that total time is normalized to 1. Leisure $h_{e,t}$ can be defined as:

$$h_{e,t} = 1 - \sum_{s=1}^{S} l_{e,t}(s)$$

where $h_{e,t} \in [0,1]$ and $l_{e,t}(s) \in [0,1]$. The parameter that regulates the Frisch elasticity of labor supply is denoted ψ_e. χ_e is a scaling factor that helps match hours worked observed in the data. The household seeks to maximize its utility by solving the following problem:

$$V_{e,t}(s) = \max_{c_{e,t}(s), x_{e,t}(s), l_{e,t}(s), k_{e,t}(s), d_{e,t}} U\left(c_{e,t}\right) - \chi_e l_{e,t}(s)^{\left(1+\frac{1}{\psi_e}\right)} + \beta E[V_{e,t+1}(s)]$$

The economic decisions for period t are subject to the following constraints:

$$d_{e,t} * DMute = (1 + \tau_t^c + \tau_t^{ex}) \sum_{s=1}^{S} c_{e,t}(s) + \sum_{s=1}^{S} x_{e,t}(s) + (1 + i_{r,t-1}) d_{e,t-1}$$

$$+ \tau_t^k \sum_{s=1}^{S} k_{e,t-1}(s) + \left[\frac{\phi}{2} \left(\sum_{s=1}^{S} k_{e,t}(s) - \sum_{s=1}^{S} k_{e,t-1}(s) \right)^2 \right]$$

$$- \ (1 - (1 - \eta_{e,t}^{i,n}) \tau_{e,t}^{i,n} - \tau_t^o - \tau_{e,t}^{i,n,f}) \sum_{s=1}^{S} w_{e,t}(s) l_{e,t}(s)$$

$$- (1 - (1 - \eta_{e,t}^{i,r}) \tau_{e,t}^{i,r} - \tau_t^o - \tau_{e,t}^{i,r,f} - \tau_t^{corp}) \sum_{s=1}^{S} r_{e,t}(s) k_{e,t-1}(s)$$

$$k_{e,t}(s) = x_{e,t}(s) + (1 - \delta) k_{e,t-1}(s)$$

$$c_{e,t}(s) \geq 0$$

$$k_{e,t}(s) \geq 0,\ k_{e,t+1}(s) = 0$$

$V_{e,t}(s)$ defines expected utility discounted at a patient factor $\beta \in [0,1]$. As in Mendoza (1991), ϕ denotes a capital adjustment cost. The return on capital lent to firms is $r_{e,t}(s)$. The wage paid to workers of type e in sector s is $w_{e,t}(s)$. Future capital stock $k_{e,t}(s)$ is the sum of current capital stock $k_{e,t-1}(s)$, accounting for depreciation δ, and investment $x_{e,t}(s)$. $i_{r,t}$ denotes the interest rate at which domestic residents can borrow from international markets in period t, and $d_{e,t}$ is household debt. $DMute$ is a parameter that accounts for the change in personal debt between 2005 and the starting year of the study. Federal Reserve data are used to calculate this parameter.

Following Schmitt-Grohé and Uribe (2003), we assume a debt elastic interest rate. This is modeled as $i_{r,t} = i_{r,w} + \zeta(e^{D_t - D} - 1)$ where $i_{r,w}$ is the world interest rate faced by domestic agents and is assumed to be constant and ζ and D are constant parameters that are calibrated to match the state's economy. $\zeta(e^{D_t - D} - 1)$ is the state specific interest rate premium that increases with the level of debt. D_t represents the aggregate state level of debt, such that $D_t = \sum_{e=1}^{E} d_{e,t}$.

τ_t^c is the tax on household consumption purchases, which includes general sales tax, and τ_t^{ex} is the excise tax rate. $\tau_{e,t}^{i,n}$ is the statutory individual labor income tax rate, and $\tau_{e,t}^{i,r}$ is the individual capital income tax rate. $\eta_{e,t}^{i,n}$ and $\eta_{e,t}^{i,r}$ are the proportions of labor income and capital income respectively that are deducted or otherwise exempt from income taxes. $\tau_{e,t}^{i,n,f}$ is the individual labor income tax collected by the federal government, and $\tau_{e,t}^{i,r,f}$ is the individual capital income tax collected by the federal government. Income tax rates depend on the individual earning ability e. τ_t^k is a tax on fixed assets owned by households. $\tau_t^{corp}$is the corporate income tax faced by the owners of capital. τ_t^o is the share of income paid to all other taxes, fees, and revenue sources for the state government not included specifically in the model.

The variables representing households' economic decisions for each period t and sector s can be summarized as the set: $\left\{\left\{c_{e,t}(s), x_{e,t}(s), l_{e,t}(s), k_{e,t+1}(s)\right\}_{s=1}^{S}, d_{e,t}\right\}_{t=0}^{\infty}$. The household then maximizes the utility function subject to the resource constraint and a no-Ponzi scheme constraint that implies that the household's debt position must be expected to grow at a rate lower than the interest rate in the long-run.

The Firm Problem

In each sector s, a large number of competitive firms produce goods according to the following constant elasticity of substitution (CES) production function:

$$y_t(s) = a_t\left(\sum_{e=1}^{E}\left((\theta_s)\left(k_{e,t-1}(s)\right)^{-\rho} + (1-\theta_s)\left(z_e\, l_{e,t}(s)\right)^{-\rho}\right)^{-\frac{1}{\rho}}\right)$$

where a_t is total factor productivity (TFP), θ_s is associated with the capital share of total output in sector s, and $\sigma_{CES} = \frac{1}{1-\rho}$ is the constant elasticity of substitution between capital and labor. z_e is labor productivity specific to a household member's earning ability. These firms solve the following profit maximization problem:

$$\Pi_t = (1-\tau_t^{CAT})a_t\left(\sum_{e=1}^{E}\left((\theta_s)\left(k_{e,t-1}(s)\right)^{-\rho} + (1-\theta_s)\left(z_e\, l_{e,t}(s)\right)^{-\rho}\right)^{-\frac{1}{\rho}}\right) - \sum_{e=1}^{E} w_{e,t}(s) l_{e,t}(s) - \sum_{e=1}^{E} r_{e,t}(s) k_{t-1}(s)$$

It is important to note that the demand for labor and capital is sector s specific. τ_t^{CAT} is a commercial activity tax, modeled as a tax on a firm's revenues.

The representative firm in sector s hires labor according to the following condition:

$$(1-\tau_t^{CAT})\,(1-\theta_s)a_t\left((\theta_s)\left(k_{e,t-1}(s)\right)^{-\rho} + (1-\theta_s)\left(z_e\, l_{e,t}(s)\right)^{-\rho}\right)^{-\frac{1}{\rho}-1}\left(z_e l_{e,t}(s)\right)^{-\rho-1} z_e = w_{e,t}(s),$$

where $w_{e.t}(s)$ is the wage rate for type e in sector s. The demand for capital is such that:

$$(1-\tau_t^{CAT})(\theta_s)a_t\left((\theta_s)\left(k_{e,t-1}(s)\right)^{-\rho} + (1-\theta_s)\left(z_e\, l_{e,t}(s)\right)^{-\rho}\right)^{-\frac{1}{\rho}-1}\left(k_{e,t-1}(s)\right)^{-\rho-1} = r_{e,t}(s),$$

We assume a_t follows a stationary mean zero autoregressive process of order 1 in the log, which can be represented in the following way:

$$(a_t) = \rho_A(a_{t-1}) + \epsilon_{A,t}$$

The innovation shock $\epsilon_{A,t}$ is drawn from a standard normal distribution.

The Government Sector

The government sets taxes and collects revenue to make purchases. Its contribution to the rainy-day fund RF_t is the excess of tax revenue plus federal government transfers net of government spending added to the previous period's balance.

$$RF_t = TR_t + FF_t - g_t + \left(1 + i_{r,t}\right)RF_{t-1}$$

Deficits—negative contributions—to the rainy-day fund reduce the fund's balance.

The state government's tax revenues TR_t are given by:

$$TR_t = \sum_{s=1}^{S}\left(\sum_{e=1}^{E}\Big(\tau_t^{CAT} y_{(e,t)}(s) + (\tau_t^c + \tau_t^{ex})c_{e,t}(s) + (1-\eta_{e,t}^{i,n})\tau_{e,t}^{i,n}\, w_{e,t}(s)l_{e,t}(s) + (1-\eta_{e,t}^{i,r})\tau_{e,t}^{i,r}\, r_{e,t}(s)k_{e,t-1}(s) + \tau_t^k k_{e,t-1}(s)\Big) + \tau_t^o\, y_t(s)\right)$$

Government spending is proportional to GDP and is specified as $g_t = \hat{g}_t y_t$. This implies that government spending is assumed to grow as the economy grows. Spending policy $\hat{g}_t$ is assumed to evolve according to:

$$\hat{g}_t = \left(1 - \rho_{g,h}\right)(\hat{g}) + \rho_{g,h}(\hat{g}_{t-1}) + \epsilon_g$$

where $\hat{g}$ is the state share of income spent by the government sector in the long-run, the steady-state equilibrium. Variables without the time subscript denote steady-state values.

The tax instruments follow the exogenous processes:

$$\tau_t^{i,n} = (1 - \rho_{i,n})\tau^{i,n} + \rho_{i,n}\tau_{t-1}^{i,n} + \epsilon_{i,n}$$
$$\tau_t^{i,r} = (1 - \rho_{i,r})\tau^{i,r} + \rho_{i,r}\tau_{t-1}^{i,r} + \epsilon_{i,r}$$
$$\tau_t^{c} = (1 - \rho_{c})\tau^{c} + \rho_{c}\tau_{t-1}^{c} + \epsilon_{c}$$
$$\tau_t^{ex} = (1 - \rho_{ex})\tau^{ex} + \rho_{ex}\tau_{t-1}^{ex} + \epsilon_{ex}$$
$$\tau_t^{corp} = (1 - \rho_{corp})\tau^{corp} + \rho_{corp}\tau_{t-1}^{corp} + \epsilon_{corp}$$
$$\tau_t^{k} = (1 - \rho_{k})\tau^{k} + \rho_{k}\tau_{t-1}^{k} + \epsilon_{k}$$
$$\tau_t^{o} = (1 - \rho_{o})\tau^{o} + \rho_{o}\tau_{t-1}^{o} + \epsilon_{o}$$
$$\tau_t^{i,n,f} = (1 - \rho_{i,n,f})\tau^{i,n,f} + \rho_{i,n,f}\tau_{t-1}^{i,n,f} + \epsilon_{i,n,f}$$
$$\tau_t^{i,r,f} = (1 - \rho_{i,r,f})\tau^{i,r,f} + \rho_{i,r,f}\tau_{t-1}^{i,r,f} + \epsilon_{i,r,f}$$
$$\eta_t^{i,n} = (1 - \rho_{\eta,n})\eta^{i,n} + \rho_{\eta,n}\tau_{t-1}^{i,n} + \epsilon_{\eta,n}$$
$$\eta_t^{i,r} = (1 - \rho_{\eta,r})\eta^{i,r} + \rho_{\eta,r}\eta_{t-1}^{i,r} + \epsilon_{\eta,r}$$

As in Schmitt-Grohé and Uribe (2003), we write the trade balance to GDP ratio (TB) in steady-state as:

$$TB = 1 - \frac{[c + x + g]}{y}$$

The Competitive Equilibrium

A competitive equilibrium is such that given the set of exogenous processes, households solve the household utility maximization problem, firms solve the profit maximization problem, and the capital and labor markets clear.

The Deterministic Steady-State

The characterization of the deterministic steady state is of interest for two reasons. First, the steady-state facilitates the calibration of the model. This is because the deterministic steady-state coincides with the average position of the model economy to a first approximation. Because of this, matching average values of endogenous variables to their observed counterparts (e.g., matching predicted and observed average values of the labor share, the consumption shares, or the trade-balance-to-output ratio) can reveal information about structural parameters that can be used in the calibration of the model. Second, the deterministic steady-state is often used as a convenient point around which to approximate equilibrium conditions of the stochastic economy (see Schmitt-Grohe and Uribe, 2003). For any variable, we denote its steady-state value by removing the time subscript.

Using the solution from the households' and firms' choice problems, the steady-state implies that:

$$1 = \beta\left[\left(1-(1-\eta_e^{i,r})\tau_e^{i,r} - \tau^o - \tau_e^{i,r,f} - \tau^{corp}\right)r_e(s) + 1 - \delta - \tau^k\right]$$

$$y(s) = a\left(\sum_{e=1}^{E}\left((\theta_s)\left(k_e(s)\right)^{-\rho} + (1-\theta_s)\left(z_e\, l_e(s)\right)^{-\rho}\right)^{-\frac{1}{\rho}}\right)$$

$$(1-\tau^{CAT})a\left[\theta_s\left(\frac{k_e(s)}{l_e(s)}\right)^{-\rho} + (1-\theta_s)z_e^{-\rho}\right]^{-\frac{1}{\rho}-1}\theta_s\left(\frac{k_e(s)}{l_e(s)}\right)^{-\rho-1} = r_e(s)$$

These expressions deliver the steady-state capital-labor ratio, which we denote $\omega_e(s)$

$$\omega_e(s) \equiv \frac{k_e(s)}{l_e(s)} = (1-\theta_s)^{-\frac{1}{\rho}}(z_e)\left(\frac{\beta^{-1} - 1 + \delta + \tau^k}{a(1-\tau^{CAT})\theta_s\left(1-(1-\eta_{e,t}^{i,r})\tau_e^{i,r} - \tau^o - \tau_e^{i,r,f} - \tau^{corp}\right)} - \theta_s\right)^{\frac{1}{\rho}}$$

The steady-state level of capital is:

$$k_e(s) = \omega_e(s)l_e(s)$$

Finally, the steady-state level of consumption can be obtained by evaluating the resource constraint at the steady-state:

$$\sum_{e=1}^{E} c_e(s) = y(s) - \delta \sum_{e=1}^{E} k_e(s) - g\mu_s - TBy(s)$$

which implies: $y = c + x + g + TBy$

As for the parameter that dictates households' preference for leisure:

$$\chi_e = \frac{\alpha_s}{(1+\tau^c+\tau^{ex})c_e(s)} \times \frac{(1-(1-\eta_{e,t}^{i,n})\tau_e^{i,n} - \tau^o - \tau_e^{i,n,f})w_e(s)}{\left(1+\frac{1}{\psi_e}\right) l_e(s)^{\frac{1}{\sigma_e}}}$$

Data and Calibration

Our data for calibrating the model come from publicly available federal and state data sources. First, we present our sources for the model's output variables. Then we present the sources for the model parameters and our empirical methodology for calibrating the model.

Output Variables

Primarily, we utilize BEA Regional Economic Accounts for Ohio for our output. All GDP variables are reported in real (2012 dollars) per capita terms using the U.S. GDP deflator reported by the BEA and, if not declared otherwise, we refer to the period of 1963-2017.

Our GDP projections use the latest GDP values for the state and apply projected growth rates for each year based on the product of a Congressional Budget Office (CBO) forecast of the national economy and average ratio of GDP between the state and the country from 1990 to 2021.[126]

For our measure of consumption, consumption expenditures on durable goods are subtracted from total personal consumption expenditures (PCE). We consider durable goods as investment goods, as is standard in the macroeconomics literature. The values for PCE are not available on the state-level prior to 1997.

[126] **10-Year Economic Projections, May 2022**, CBO.gov (Last visited August 2022).

We therefore use the long-run average share of consumption in GDP to obtain the level of consumption for each year from 1963-1997. Because the BEA does not report private fixed investment at the state level, we use the U.S. share of non-residential investment in GDP from the BEA, and multiply it by the state GDP to estimate non-residential gross investment. The sum of non-residential investment and consumption expenditures on durable goods represents our measure of investment. Our methodology excludes residential investment from our measure of investment (residential investment is excluded from GDP as well).

We base our employment data for the number of non-farm jobs on data from the Bureau of Labor Statistics. We calculate the employment shares per sector using data from the BEA Regional Economic Accounts. We took the average weekly hours worked from the Annual Social and Economic Supplement of the Current Population Survey. The average weekly hours worked at all jobs is divided by the total number of hours per week (168 hours) to calculate average labor supply used for the model calibration. For the baseline projections, employment is assumed to grow at the forecasted rates of employment from the CBO.[127]

We used the following methodology to estimate the effects of the tax policy scenarios on employment because the model measures employment in hours worked (intensive margin). First, we use employment multiplied by the average hours worked per year (2,102 hours). This total number of hours worked per year is multiplied by the effect of the corresponding scenario in order to obtain the change in total hours worked for each scenario. Finally, the change in hours is converted into the number of full-time equivalent jobs gained or lost by dividing it by 2,080, which is the number of hours worked by a full-time equivalent employee according to the CBO's definition (Harris and Mok, 2015).[128]

Model Parameters and Calibration

Typically, a calibration assigns values to the model parameters by matching first and second moments of the data that the model aims to explain. We utilize moments in state and federal data to estimate the model parameters.

Because depreciation data are not reported at the state level by the BEA, we refer to data for the U.S. economy. The sum of current cost depreciation in nonresidential private fixed assets and consumer durable goods is divided by the

[127] *Ibid.*
[128] Edward Harris and Shannon Mok, **How CBO Estimates the Effects of the Affordable Care Act on the Labor Market**, working paper 2015-09, Congressional Budget Office, December 2015.

sum of current cost net stock of nonresidential private fixed assets and consumer durable goods for the years 1963-2021. The average over this period represents the depreciation rate in our model. The depreciation rate of capital is $\delta = 0.1$.

The world interest rate is $i_{r,w} = 0.04$, based on the difference between the nominal interest rate for three-month treasury bill and the GDP deflator.

To compute the sector-specific labor shares, we use data from the BEA Regional Income Division. Similar to Gomme and Rupert (2004), we divide the compensation of employees by the personal income for each sector.[129] As personal income is not available for sectors, we construct it by multiplying the earnings per sector by the total economy's personal income-to-earnings ratio, which is from the BEA Regional Income Division. The capital share is simply one minus the labor share. The values refer to the years 2013-2021. The sector specific parameter θ_s is set to match the observed average labor shares for each of the $S = 9$ production sectors.[130] In the present model, the labor share is given by the ratio of labor income to output which is $1 - \theta_s$ at all times. To ensure that capital and investment are not being overstated (or understated), the parameter ν, a cost on holding capital, is applied to adjust the steady state rental rate of capital, calibrating it to match the state's investment share of GDP.[131]

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[129] Paul Gomme and Peter Rupert, **Measuring Labors Share of Income**, working paper, Federal Reserve Bank of Cleveland, Policy Discussion Paper number 04-07, November 2004.
[130] See complete list of sectors in the Tax Model Parameters section.
[131] The holding cost of capital is incorporated mathematically in the following way to steady state rental rate of capital: $r^*_{e,s} = \frac{\frac{1}{\beta} + \tau^k_e + \nu - (1-\delta)}{(1-(1-\eta^{i,r}_{e,t})\tau^{i,r}_e - \tau^{i,r,f}_e - \tau^{co} - \tau^s_s - \tau^o)}$.

The earning ability for household types is based on the distribution of income and population as reported in the Ohio Department of Revenue individual income tax annual report for Tax Year 2021.[132]

- Earning ability 1 has an adjusted gross income (AGI) of up to $20,000 per year;
- Earning ability 2 has an AGI from $20,000 to $50,000;
- Earning ability 3 has an AGI from $50,000 to $75,000;
- Earning ability 4 has an AGI from $75,000 to $100,000;
- Earning ability 5 has an AGI from $100,000 to $150,000;
- Earning ability 6 has an AGI from $150,000 to $200,000;
- Earning ability 7 has an AGI from $200,000 to $250,000;
- Earning ability 8 has an AGI from $250,000-$500,000;
- Earning ability 9 has an AGI from $500,000 to $1,000,000; and
- Earning ability 10 has an AGI of more than $1,000,000 per year.

The share of household members by earning ability, q^e, is the share of returns per earning ability group. The labor productivity per earning ability, z_e, is the income per return for each earning ability with the labor productivity for group 1 being normalized to one. We take our Frisch elasticity estimate $\psi_e = 0.4$ from Reichling and Whalen (2012).[133] The parameter D is set to match the observed average trade-balance to output ratio since $TB = i_{r,w}\frac{D}{y}$. We estimate tax rates similar to the methodology used by McDaniel (2007).[134]

The full list of parameters is included in the following sections.

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[132] Ohio Department of Taxation, **Ohio Department of Taxation Annual Report Fiscal Year 2021**, 2022.
[133] Felix Reichling and Charles Whalen, **Review of Estimates of the Frisch Elasticity of Labor Supply**, working paper 2012-13, Congressional Budget Office, October 2012.
[134] A complete explanation of the methodology is included in the Tax Mode Parameters section; Cara McDaniel, **Average tax rates on consumption, investment, labor, and capital in the OECD 1950-2003**, working paper, March 2007.

Appendix B: The Buckeye Institute's Economic Research Center Tax Model Parameters

Tax Rate Estimates

The state tax rates calculated in this paper are average Ohio tax rates. The general strategy employed is as follows. First, total income is categorized as labor income or capital income and private expenditures are categorized as consumption or investment. Second, tax revenues are classified as revenues generated from taxes on labor income, capital income, private consumption expenditures, or private investment. To find a given tax rate, we divide each category of tax revenue by the corresponding income or expenditure. Since we compute tax rates in the same fashion each year, we drop time subscripts for the rest of this section.

Data on tax revenues come from U.S. Census Bureau Survey of State Government Tax Collections (STC) and the Ohio Department of Taxation's Annual Report for Fiscal Year 2021.[135] Data on income and expenditures come from regional BEA data. In any given year, total tax revenues collected by the government are the sum of taxes on production and imports (TPI), social security contributions, direct taxes on households (HHT), and direct taxes on corporations. The following sections detail the steps we take to categorize these tax revenues and calculate average tax rates.

Share of the Income Tax that Falls on Labor

The average tax rate on labor income is found by dividing labor income tax revenues by economy-wide total wage and salary labor income. To compute the labor income tax rate, we calculate labor income tax revenues and labor income. Labor income tax revenues come from two sources: the household income tax and social security taxes. However, household income taxes represent taxes on total income. Since only a portion of this income is generated from labor, only a portion of these taxes reflects taxes on labor income.

Unfortunately, the STC and BEA do not break down household income taxes according to type of income. For this reason, papers calculating average tax rates on labor and capital income based on aggregate data, such as Mendoza et al.

[135] **2020 Annual Survey of State Government Tax Collections Detailed Table**, U.S. Department of Commerce, U.S. Census Bureau (Last visited August 2022); and Ohio Department of Taxation, **Ohio Department of Taxation Annual Report 2021**, 2022.

(1994), assume that the tax rate on household labor income is the same as the tax rate on household capital income.[136] We make the same assumption.

The federal income tax rate is found by dividing total federal taxes on income of the household, $FHHT$, by total household income in each period. Household income is defined as gross domestic product less net taxes on production and imports, or $GDP - (TPI - Sub)$. The household income tax rate is therefore measured as:

$$\tau^{i,f} = \frac{FHHT}{GDP - (TPI - Sub)}$$

It remains to divide income into payment to capital and payment to labor. Let θ be the share of income attributed to capital, with the remaining $(1 - \theta)$ share attributed to labor. Total household income taxes paid on labor income are represented by

$$FHHT_L = \tau^{i,l,f}(1-\theta)\big(GDP - (TPI - Sub)\big)$$

The second source of tax revenue generated from taxes on labor income are social security taxes, *SS*. This corresponds to an exact entry in the BEA data, no further adjustment is required. Social security taxes combined with *HHTL* represent total tax revenues that are classified as taxes paid on labor income, so the average tax rate on labor income is measured as:

$$\tau^{i,n,f} = \frac{SS + FHHT_L}{(1-\theta)\big(GDP - (TPI - Sub)\big)}$$

136 Enrique G. Mendoza, Assaf Razin, and Linda L. Tesar, "**Effective tax rates in macroeconomics: Cross-country estimates of tax rates on factor incomes and consumption**," *Journal of Monetary Economics*, Volume 34, Issue 3 (December 1994) p.297-323.

At the state level, we calculate income tax rates for a variety of earning groups. The state income tax rate is found by dividing total state taxes on income of the household, $SHHT_e$, by total household income in each period. Household income, total state taxes on income of the household, as well as population are distributed according to the distribution reported in the Ohio Department of Taxation's Annual Report for Fiscal Year 2021.[137] Household income is defined as gross domestic product less net taxes on production and imports, or $GDP - (TPI - Sub)$. The household income tax rate is therefore measured as:

$$\tau^i = \frac{SHHT_e}{\big(GDP - (TPI - Sub)\big)_i}$$

It remains to divide income into payment to capital and payment to labor. Let θ be the share of income attributed to capital, with the remaining (1 − θ) share attributed to labor. Total household income taxes paid on labor income are represented by

$$SHHT_{e,i} = \tau^{i,n}(1 - \theta)\big(GDP - (TPI - Sub)\big)_i$$

The average state tax rate on labor income is measured as:

$$\tau^{i,n} = \frac{SHHT_{e,i}}{(1 - \theta)\big(GDP - (TPI - Sub)\big)_i}$$

Consumption and Investment Tax Rates

Revenue collected from taxes levied on consumption and investment expenditures are included in taxes on production and imports, TPI. Consumption and investment expenditures are subsidized by the amount Sub. TPI includes general taxes on goods and services, excise taxes, import duties and property taxes. The task remains to properly allocate TPI to the relevant tax revenue category. This requires the proper division of TPI across consumption and investment. TPI includes the following components: Property taxes, general taxes on goods and services, excise taxes, taxes on specific services, and taxes on the use of goods to perform activities.

Some of the taxes included in TPI fall only on consumption expenditures. Others fall on both consumption and investment expenditures. Revenue from taxes that fall on both consumption and investment expenditures are assumed to be split

[137] Ohio Department of Taxation, **Ohio Department of Taxation Annual Report 2021**, 2022.

between consumption tax revenue and investment tax revenue according to consumption and investment share in private expenditures. Taxes that fall strictly on consumption are excise taxes and taxes on specific services, reported as select sales taxes in the STC data.

Taxes that fall on both consumption and investment are general sales and use taxes, and taxes on use of goods to perform activities, which includes motor vehicle taxes, highway taxes, license taxes, etc. These goods are used in the production of both investment goods and consumption goods, and can be calculated by subtracting select sales taxes, total income taxes, and corporation license taxes from total taxes in the STC data.

After identifying taxes that fall strictly on consumption expenditures, we calculate λ, their share of TPI. Revenue collected from taxes levied on consumption expenditures is calculated as:

$$TPI_C = \left(\lambda + (1-\lambda)\left(\frac{C}{C+I}\right)\right)(TPI - Sub)$$

Consumption expenditures are reported in the national accounts gross of taxes. Taxable consumption expenditures are then $C - TPI_c$ and the consumption tax is measured as:

$$\tau^C = \frac{TPI_C}{C}$$

Since TPI_c represents revenue from consumption taxes, the remaining portion of $TPI - Sub$ is attributed to taxes on investment.

$$TPI_X = TPI - Sub - TPI_C$$

Share of the Income Tax that Falls on Capital

As calculated previously, income paid to capital in the economy is $\theta(GDP - (TPI - Sub))$. $OSGOV$ is gross operating surplus earned by the government, and therefore is not subject to tax. Taxable capital income is therefore $\theta(GDP - (TPI - Sub)) - OSGOV$. Capital tax revenues come from the following sources: the household income tax, and taxes levied on corporate income. Federal household taxes on capital, $FHHT_K$, is then

$$FHHT_K = \tau^{i,r,f}\theta\big(GDP - (TPI - Sub)\big)$$

The federal household capital income tax rate is then

$$\tau^{i,k,f} = \frac{FHHT_k}{\theta\big(GDP - (TPI - Sub)\big) - OSGOV}$$

Federal corporate tax data (FCT) is only available at the national level, therefore we first approximate the share of corporate tax paid by Ohio.

The federal corporate tax rate is computed using national data as:

$$\tau^{CT,F} = \frac{FCT}{\theta\big(GGDP - (TPI - Sub)\big) - OSGOV}$$

As owners of corporations, households are subject to all corporate taxation. The total federal capital income tax is then:

$$\tau^{i,r,f} = \tau^{CT,F} + \tau^{i,k,f}$$

At the state level household capital income tax is

$$SHHT_{K,i} = \tau^{i,k}\left(\theta\big(GDP - (TPI - Sub)\big)_i\right)$$

Where the household income and tax burden are once again distributed according to the distribution reported in the Ohio Department of Taxation's Annual Report for Fiscal Year 2021.[138]

The state household capital income tax rate is then

$$\tau^{i,r} = \frac{\left(SHHT_{K,i} + SCT_i\right)}{\theta\big(GDP - (TPI - Sub)\big)_i - OSGOV_i}$$

Sectors

Our model uses nine production sectors. The BEA reports GDP for each two-digit North American Industry Classification System (NAICS) industries, which we use to calculate each sector's percentage in total GDP (see Table B-4). Some of our sectors are the same as reported by the BEA, the remaining sectors are constructed by combining several NAICS industries as shown in Table B-1.

[138] Ohio Department of Taxation, **Ohio Department of Taxation Annual Report 2021**, 2022.

Table B-1: Definition of Sectors

Sector	NAICS Sectors
Agriculture, Forestry, Fishing, and Hunting	Agriculture, Forestry, Fishing, and Hunting
Mining	Mining
Utilities, Transportation, and Warehousing	Utilities Transportation and Warehousing
Construction	Construction
Manufacturing	Manufacturing
Trade	Wholesale Trade Retail Trade
Services	Information Finance and Insurance Professional, Scientific, and Technical Services Management of Companies and Enterprises Administrative and Waste Management Services Educational Services Arts, Entertainment, and Recreation Accommodation and Food Services Other Services
Real Estate, Rental, and Leasing	Real Estate Rental and Leasing
Health Care and Social Assistance	Health Care and Social Assistance

Parameters for Ohio

The following tables present the calibrated parameters for the model.

Table B-2: Ohio Household Parameters*

Disutility of Labor	$\chi_e = 240.0$
Real Interest Rate	$i_{r,w} = 0.04$
Annual Depreciation Rate of Capital	$\delta = 0.1$
Frisch Elasticity of Labor Supply	$\psi_e = 0.4$
Holding Cost of Capital	$\nu = -0.0103$

*The real interest rate is based on the difference between the nominal interest rate for three-month Treasury bill and the GDP deflator from 1950 to 2015 using St. Louis Federal Reserve Bank FRED data. The annual depreciation rate of capital is based on data from the BEA for the U.S. economy. It is the average of the sum of current cost depreciation in nonresidential private fixed assets and consumer durable goods divided by the sum of current cost net stock of nonresidential private fixed assets and consumer durable goods for the years 1963 to 2015. The Frisch elasticity of labor supply is based on the central estimate from Reichling and Whalen (2012).

Table B-3: Ohio Labor Productivity

Labor Productivity	Population Distribution
$z_1 = 1$	$q^1 = 0.248$
$z_2 = 3.45$	$q^2 = 0.326$
$z_3 = 6.25$	$q^3 = 0.159$
$z_4 = 8.88$	$q^4 = 0.095$
$z_5 = 12.51$	$q^5 = 0.098$
$z_6 = 18.27$	$q^6 = 0.034$
$z_7 = 24.66$	$q^7 = 0.014$
$z_8 = 39.91$	$q^8 = 0.019$
$z_9 = 97.11$	$q^9 = 0.005$
$z_{10} = 1317.01$	$q^{10} = 0.002$

Table B-4: Ohio Sector Specific Parameters

Sector	Output Share	Employment Share	Capital Share
Agriculture, Forestry, Fishing, and Hunting	$\alpha_1 = 0.007$	$\mu_1 = 0.017$	$\theta_1 = 0.655$
Mining	$\alpha_2 = 0.009$	$\mu_2 = 0.005$	$\theta_2 = 0.545$
Utilities, Transportation, and Warehousing	$\alpha_3 = 0.054$	$\mu_3 = 0.049$	$\theta_3 = 0.450$
Construction	$\alpha_4 = 0.041$	$\mu_4 = 0.055$	$\theta_4 = 0.513$
Manufacturing	$\alpha_5 = 0.185$	$\mu_5 = 0.116$	$\theta_5 = 0.321$
Trade	$\alpha_6 = 0.137$	$\mu_6 = 0.153$	$\theta_6 = 0.352$
Services	$\alpha_7 = 0.344$	$\mu_7 = 0.415$	$\theta_7 = 0.387$
Real Estate, Rental, and Leasing	$\alpha_8 = 0.127$	$\mu_8 = 0.045$	$\theta_8 = 0.578$
Health Care and Social Assistance	$\alpha_9 = 0.098$	$\mu_9 = 0.146$	$\theta_9 = 0.345$

Table B-5: Ohio Federal Tax Parameters

Federal individual labor income tax rate for AGI 1	$\tau_{1}^{i,n,f} = 0.0030$
Federal individual capital income tax rate for AGI 1	$\tau_{1}^{i,r,f} = 0.0028$
Federal individual labor income tax rate for AGI 2	$\tau_{2}^{i,n,f} = 0.0354$
Federal individual capital income tax rate for AGI 2	$\tau_{2}^{i,r,f} = 0.0339$
Federal individual labor income tax rate for AGI 3	$\tau_{3}^{i,n,f} = 0.0429$
Federal individual capital income tax rate for AGI 3	$\tau_{3}^{i,r,f} = 0.0409$
Federal individual labor income tax rate for AGI 4	$\tau_{4}^{i,n,f} = 0.0477$
Federal individual capital income tax rate for AGI 4	$\tau_{4}^{i,r,f} = 0.0454$
Federal individual labor income tax rate for AGI 5	$\tau_{5}^{i,n,f} = 0.0634$
Federal individual capital income tax rate for AGI 5	$\tau_{5}^{i,r,f} = 0.0619$
Federal individual labor income tax rate for AGI 6	$\tau_{6}^{i,n,f} = 0.0634$
Federal individual capital income tax rate for AGI 6	$\tau_{6}^{i,r,f} = 0.0619$
Federal individual labor income tax rate for AGI 7	$\tau_{7}^{i,n,f} = 0.1283$
Federal individual capital income tax rate for AGI 7	$\tau_{7}^{i,r,f} = 0.1192$
Federal individual labor income tax rate for AGI 8	$\tau_{8}^{i,n,f} = 0.0944$
Federal individual capital income tax rate for AGI 8	$\tau_{8}^{i,r,f} = 0.0892$
Federal individual labor income tax rate for AGI 9	$\tau_{9}^{i,n,f} = 0.1323$
Federal individual capital income tax rate for AGI 9	$\tau_{9}^{i,r,f} = 0.1235$
Federal individual labor income tax rate for AGI 10	$\tau_{10}^{i,n,f} = 0.1494$
Federal individual capital income tax rate for AGI 10	$\tau_{10}^{i,r,f} = 0.1399$

Table B-6: Ohio Income Tax Parameters I

State individual labor income tax rate for AGI 1	$\tau_1^{i,n} = 0.0000$
State individual capital income tax rate for AGI 1	$\tau_1^{i,r} = 0.0000$
State individual labor income tax rate for AGI 2	$\tau_2^{i,n} = 0.0128$
State individual capital income tax rate for AGI 2	$\tau_2^{i,r} = 0.0128$
State individual labor income tax rate for AGI 3	$\tau_3^{i,n} = 0.0207$
State individual capital income tax rate for AGI 3	$\tau_3^{i,r} = 0.0207$
State individual labor income tax rate for AGI 4	$\tau_4^{i,n} = 0.0234$
State individual capital income tax rate for AGI 4	$\tau_4^{i,r} = 0.0234$
State individual labor income tax rate for AGI 5	$\tau_5^{i,n} = 0.0266$
State individual capital income tax rate for AGI 5	$\tau_5^{i,r} = 0.0266$
State individual labor income tax rate for AGI 6	$\tau_6^{i,n} = 0.0294$
State individual capital income tax rate for AGI 6	$\tau_6^{i,r} = 0.0294$
State individual labor income tax rate for AGI 7	$\tau_7^{i,n} = 0.0311$
State individual capital income tax rate for AGI 7	$\tau_7^{i,r} = 0.0311$
State individual labor income tax rate for AGI 8	$\tau_8^{i,n} = 0.0328$
State individual capital income tax rate for AGI 8	$\tau_8^{i,r} = 0.0328$
State individual labor income tax rate for AGI 9	$\tau_9^{i,n} = 0.0346$
State individual capital income tax rate for AGI 9	$\tau_9^{i,r} = 0.0346$
State individual labor income tax rate for AGI 10	$\tau_{10}^{i,n} = 0.0355$
State individual capital income tax rate for AGI 10	$\tau_{10}^{i,r} = 0.0355$

Table B-7: Ohio Income Tax Parameters II

State individual labor income tax exemption rate for AGI 1	$\eta_1^{i,n} = 0.0000$
State individual capital income tax exemption rate for AGI 1	$\eta_1^{i,r} = 0.0000$
State individual labor income tax exemption rate for AGI 2	$\eta_2^{i,n} = 0.4327$
State individual capital income tax exemption rate for AGI 2	$\eta_2^{i,r} = 0.3957$
State individual labor income tax exemption rate for AGI 3	$\eta_3^{i,n} = 0.3803$
State individual capital income tax exemption rate for AGI 3	$\eta_3^{i,r} = 0.3399$
State individual labor income tax exemption rate for AGI 4	$\eta_4^{i,n} = 0.3787$
State individual capital income tax exemption rate for AGI 4	$\eta_4^{i,r} = 0.3381$
State individual labor income tax exemption rate for AGI 5	$\eta_5^{i,n} = 0.3675$
State individual capital income tax exemption rate for AGI 5	$\eta_5^{i,r} = 0.3262$
State individual labor income tax exemption rate for AGI 6	$\eta_6^{i,n} = 0.3709$
State individual capital income tax exemption rate for AGI 6	$\eta_6^{i,r} = 0.3299$
State individual labor income tax exemption rate for AGI 7	$\eta_7^{i,n} = 0.4065$
State individual capital income tax exemption rate for AGI 7	$\eta_7^{i,r} = 0.3678$
State individual labor income tax exemption rate for AGI 8	$\eta_8^{i,n} = 0.4458$
State individual capital income tax exemption rate for AGI 8	$\eta_8^{i,r} = 0.4096$
State individual labor income tax exemption rate for AGI 9	$\eta_9^{i,n} = 0.5400$
State individual capital income tax exemption rate for AGI 9	$\eta_9^{i,r} = 0.5099$
State individual labor income tax exemption rate for AGI 10	$\eta_{10}^{i,n} = 0.8931$
State individual capital income tax exemption rate for AGI 10	$\eta_{10}^{i,r} = 0.8862$

Table B-8: Ohio Tax Parameters

General sales tax rate (effective rate)	τ^c=0.0286
Excise tax rate (effective rate)	τ^{ex}=0.0152
State tax revenues proportion of GDP	$\frac{TR}{Y}$ = 0.0459
Other state tax collections rate Debt adjustment factor	τ^o=0.00047
Debt Adjustment Factor	DMute = 0.80

Parameters for California

The following tables present the calibrated parameters for the model.

Table B-9: California Household Parameters*

Disutility of Labor	$\chi_e = 292.0$
Real Interest Rate	$i_{r,w} = 0.04$
Annual Depreciation Rate of Capital	$\delta = 0.1$
Frisch Elasticity of Labor Supply	$\psi_e = 0.4$
Holding Cost of Capital	$\nu = 0.0089$

*The real interest rate is based on the difference between the nominal interest rate for three-month Treasury bill and the GDP deflator from 1950 to 2015 using St. Louis Federal Reserve Bank FRED data. The annual depreciation rate of capital is based on data from the BEA for the U.S. economy. It is the average of the sum of current cost depreciation in nonresidential private fixed assets and consumer durable goods divided by the sum of current cost net stock of nonresidential private fixed assets and consumer durable goods for the years 1963 to 2015. The Frisch elasticity of labor supply is based on the central estimate from Reichling and Whalen (2012).

Table B-10: California Labor Productivity

Labor Productivity	Population Distribution
$z_1 = 1$	$q^1 = 0.238$
$z_2 = 3.21$	$q^2 = 0.310$
$z_3 = 5.91$	$q^3 = 0.139$
$z_4 = 8.16$	$q^4 = 0.088$
$z_5 = 11.43$	$q^5 = 0.096$
$z_6 = 15.97$	$q^6 = 0.048$
$z_7 = 22.19$	$q^7 = 0.020$
$z_8 = 28.82$	$q^8 = 0.044$
$z_9 = 60.47$	$q^9 = 0.012$
$z_{10} = 284.57$	$q^{10} = 0.006$

Table B-11: California Sector Specific Parameters

Sector	Output Share	Employment Share	Capital Share
Agriculture, Forestry, Fishing, and Hunting	$\alpha_1 = 0.0065$	$\mu_1 = 0.0374$	$\theta_1 = 0.5697$
Mining	$\alpha_2 = 0.0086$	$\mu_2 = 0.0283$	$\theta_2 = 0.3961$
Utilities, Transportation, and Warehousing	$\alpha_3 = 0.0544$	$\mu_3 = 0.0281$	$\theta_3 = 0.4493$
Construction	$\alpha_4 = 0.0405$	$\mu_4 = 0.0076$	$\theta_4 = 0.4592$
Manufacturing	$\alpha_5 = 0.1848$	$\mu_5 = 0.0926$	$\theta_5 = 0.2957$
Trade	$\alpha_6 = 0.1366$	$\mu_6 = 0.6119$	$\theta_6 = 0.3701$
Services	$\alpha_7 = 0.3437$	$\mu_7 = 0.0875$	$\theta_7 = 0.3883$
Real Estate, Rental, and Leasing	$\alpha_8 = 0.1272$	$\mu_8 = 0.0625$	$\theta_8 = 0.7263$
Health Care and Social Assistance	$\alpha_9 = 0.0975$	$\mu_9 = 0.0261$	$\theta_9 = 0.3439$

Table B-12: California Federal Tax Parameters

Federal individual labor income tax rate for AGI 1	$\tau_1^{i,n,f} = 3.13e-4$
Federal individual capital income tax rate for AGI 1	$\tau_1^{i,r,f} = 3.13e-4$
Federal individual labor income tax rate for AGI 2	$\tau_2^{i,n,f} = 3.90e-7$
Federal individual capital income tax rate for AGI 2	$\tau_2^{i,r,f} = 3.90e-7$
Federal individual labor income tax rate for AGI 3	$\tau_3^{i,n,f} = 7.95e-7$
Federal individual capital income tax rate for AGI 3	$\tau_3^{i,r,f} = 7.95e-7$
Federal individual labor income tax rate for AGI 4	$\tau_4^{i,n,f} = 1.89e-6$
Federal individual capital income tax rate for AGI 4	$\tau_4^{i,r,f} = 1.89e-6$
Federal individual labor income tax rate for AGI 5	$\tau_5^{i,n,f} = 1.12e-4$
Federal individual capital income tax rate for AGI 5	$\tau_5^{i,r,f} = 1.12e-4$
Federal individual labor income tax rate for AGI 6	$\tau_6^{i,n,f} = 1.12e-4$
Federal individual capital income tax rate for AGI 6	$\tau_6^{i,r,f} = 1.12e-4$
Federal individual labor income tax rate for AGI 7	$\tau_7^{i,n,f} = 3.34e-3$
Federal individual capital income tax rate for AGI 7	$\tau_7^{i,r,f} = 3.34e-3$
Federal individual labor income tax rate for AGI 8	$\tau_8^{i,n,f} = 3.34e-3$
Federal individual capital income tax rate for AGI 8	$\tau_8^{i,r,f} = 3.34e-3$
Federal individual labor income tax rate for AGI 9	$\tau_9^{i,n,f} = 4.96e-3$
Federal individual capital income tax rate for AGI 9	$\tau_9^{i,r,f} = 4.96e-3$
Federal individual labor income tax rate for AGI 10	$\tau_{10}^{i,n,f} = 4.80e-3$
Federal individual capital income tax rate for AGI 10	$\tau_{10}^{i,r,f} = 4.80e-3$

Table B-13: California Income Tax Parameters I

State individual labor income tax rate for AGI 1	$\tau_1^{i,n} = 0.0111$
State individual capital income tax rate for AGI 1	$\tau_1^{i,r} = 0.0111$
State individual labor income tax rate for AGI 2	$\tau_2^{i,n} = 0.0209$
State individual capital income tax rate for AGI 2	$\tau_2^{i,r} = 0.0209$
State individual labor income tax rate for AGI 3	$\tau_3^{i,n} = 0.0369$
State individual capital income tax rate for AGI 3	$\tau_3^{i,r} = 0.0369$
State individual labor income tax rate for AGI 4	$\tau_4^{i,n} = 0.0486$
State individual capital income tax rate for AGI 4	$\tau_4^{i,r} = 0.0486$
State individual labor income tax rate for AGI 5	$\tau_5^{i,n} = 0.0602$
State individual capital income tax rate for AGI 5	$\tau_5^{i,r} = 0.0602$
State individual labor income tax rate for AGI 6	$\tau_6^{i,n} = 0.0695$
State individual capital income tax rate for AGI 6	$\tau_6^{i,r} = 0.0695$
State individual labor income tax rate for AGI 7	$\tau_7^{i,n} = 0.0761$
State individual capital income tax rate for AGI 7	$\tau_7^{i,r} = 0.0761$
State individual labor income tax rate for AGI 8	$\tau_8^{i,n} = 0.0800$
State individual capital income tax rate for AGI 8	$\tau_8^{i,r} = 0.0800$
State individual labor income tax rate for AGI 9	$\tau_9^{i,n} = 0.0936$
State individual capital income tax rate for AGI 9	$\tau_9^{i,r} = 0.0936$
State individual labor income tax rate for AGI 10	$\tau_{10}^{i,n} = 0.1144$
State individual capital income tax rate for AGI 10	$\tau_{10}^{i,r} = 0.1144$

Table B-14: California Income Tax Parameters II

State individual labor income tax exemption rate for AGI 1	$\eta_1^{i,n} = 0.9326$
State individual capital income tax exemption rate for AGI 1	$\eta_1^{i,r} = 0.8591$
State individual labor income tax exemption rate for AGI 2	$\eta_2^{i,n} = 0.7851$
State individual capital income tax exemption rate for AGI 2	$\eta_2^{i,r} = 0.5512$
State individual labor income tax exemption rate for AGI 3	$\eta_3^{i,n} = 0.7170$
State individual capital income tax exemption rate for AGI 3	$\eta_3^{i,r} = 0.4089$
State individual labor income tax exemption rate for AGI 4	$\eta_4^{i,n} = 0.6815$
State individual capital income tax exemption rate for AGI 4	$\eta_4^{i,r} = 0.3348$
State individual labor income tax exemption rate for AGI 5	$\eta_5^{i,n} = 0.6450$
State individual capital income tax exemption rate for AGI 5	$\eta_5^{i,r} = 0.2585$
State individual labor income tax exemption rate for AGI 6	$\eta_6^{i,n} = 0.6019$
State individual capital income tax exemption rate for AGI 6	$\eta_6^{i,r} = 0.1685$
State individual labor income tax exemption rate for AGI 7	$\eta_7^{i,n} = 0.5597$
State individual capital income tax exemption rate for AGI 7	$\eta_7^{i,r} = 0.0803$
State individual labor income tax exemption rate for AGI 8	$\eta_8^{i,n} = 0.5275$
State individual capital income tax exemption rate for AGI 8	$\eta_8^{i,r} = 0.0132$
State individual labor income tax exemption rate for AGI 9	$\eta_9^{i,n} = 0.4904$
State individual capital income tax exemption rate for AGI 9	$\eta_9^{i,r} = -0.0643$
State individual labor income tax exemption rate for AGI 10	$\eta_{10}^{i,n} = 0.2722$
State individual capital income tax exemption rate for AGI 10	$\eta_{10}^{i,r} = -0.5202$

Table B-15: California Tax Parameters

General sales tax rate (effective rate)	τ^c=0.0286
Excise tax rate (effective rate)	τ^{ex}=0.0152
State tax revenues proportion of GDP	$\frac{TR}{Y} = 0.0459$
Other state tax collections rate Debt adjustment factor	τ^o=0.00047
Debt Adjustment Factor	DMute = 0.80

About the Authors

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Prior to joining Buckeye, Hederman was director, and a founding member of the Center for Data Analysis (CDA) at the Heritage Foundation, where he served as the organization's top "number cruncher." Under Hederman's leadership, the CDA provided state-of-the-art economic modeling, database products, and original studies.

While at Heritage, Hederman also oversaw the organization's technical research on taxes, healthcare, income and poverty, entitlements, energy, education, and employment, among other policy and economic issues. He was also responsible for managing Heritage's legislative statistical analysis and econometric modeling.

Hederman's commentary has been published in *The Washington Post*, *The Washington Times*, *National Affairs*, *The Hill*, National Review Online, and FoxNews.com, among others. He is regularly quoted by major newspapers and wire services, and has appeared on Fox News Channel, CNN, CNBC, and MSNBC.

Hederman graduated from Georgetown Public Policy Institute with a Master of Public Policy degree and holds a Bachelor of Arts from the University of Virginia.

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While at The Buckeye Institute, Reed was working on his PhD dissertation in natural resource economics at West Virginia University. Reed's dissertation examines the economic and technical impact on the electricity generation system of New York's Climate Leadership and Community Protection Act, which requires 70 percent of New York's electricity to come from green sources by 2030.

Prior to undertaking PhD studies, Reed was a chemical engineer focused on research and development of electricity generation technology, and policy and regulatory analysis related to U.S. energy policy. He worked at the National Energy Technology Laboratory and the Idaho National Laboratory where he performed analysis of advanced energy systems. Reed also worked at General Motors where he was an energy business intelligence analyst providing research and insights for company executives, its board of directors, and other senior management.

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Before joining The Buckeye Institute, Lewis interned with the Cato Institute and Citizens Against Government Waste. While at Cato, he worked under the direction of scholars at the Herbert A. Stiefel Center for Trade Policy Studies, where he assisted trade policy experts with their research. While at Citizens Against Government Waste, Lewis researched spending bills, analyzed the impact of tax policies, and produced several blogs highlighting wasteful government expenditure at the state and federal levels.

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