CHOICES

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C-FARE 2023 Brandt Forum Theme: Agriculture and Environmental Policy[1]

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Introduction

Concerns about climate change, the environment, food security and resilience, and the agricultural sector's economic viability have led to various government interventions. While economists advocate for financial incentives like a carbon tax, most interventions are through regulations and subsidies. One explanation the late Martin Weitzman provided is uncertainty about policy outcomes and industry behavior (Weitzman, 1974). Other alternative explanations for policy choices include political economy and political power that affects the distribution of benefits and costs.

These approaches may explain both environmental and agricultural policies. In the case of environmental policies, the political environment elects not to use a carbon tax and, instead, uses various forms of command and control and subsidies. In agriculture, a mixture of semi-market-based policies—including, crop insurance, storage control, and conservation reserve program—co-exists alongside an element of subsidy.

The desire of incumbent governments to establish irreversible outcomes given political uncertainty leads them to incentivize the early adoption of the technology and set facts on the ground. The government promotes the early adoption of technologies, thus establishing policy durability (Hochman and Zilberman, 2021). In the current thematic issue, Hochman and Zilberman extend the proposed framework and discuss policy choices and how dynamic consideration may lead to a ratcheting-up effect whereby policy starts via command and control and, under certain conditions, transitions to market-based incentives, while other conditions lead to more stringent policy over time.

Articles in this Theme:

Additional explanations for policy use include uncertainty and credit constraints, which constrain the establishment of new industries and supply chains. In this respect, Zilberman et al. explore the importance of innovation and product supply chains. They focuses on modern agriculture, characterized by high rates of innovation and share of food production outside the farm gate, and

[1] The C-FARE Brand Forum (https://www.cfare.org/brandt-forum) is an annual event established to honor the late Dr. Jon Brandt's many contributions to our profession (https://www.aaea.org/trust/special-purpose-funds/jon-brandt-special-purpose-fund).

discusses innovative supply chains. Their work suggests that agricultural policy should invest in research and development while recognizing the behavior of these supply chains, thus providing incentives for the creation of novel and value-enhancing supply chains.

When looking at the added value of policy and the political economy of its making, Muhammad and Trejo-Pech show that policy design is not the outcome of political lobbying of producers versus consumers. Instead, the mobilization of special interest groups results in the ushering in of a protective trade policy, the Trump administration's Section 232 tariffs, with quotas on imported steel and significant ramifications to U.S. canned food producers. They argue that the complexity of the production supply chains suggests particular interest groups with concentrated interests in steel production, not interests of producers versus consumers, guided that trade policy.

Wu discusses commonly used criteria to target resources for conservation and their environmental and political-economic implications. That work also highlights the challenge of designing an efficient conservation program, focusing on strong nonlinearities and ecosystem linkages that militate against the politically palatable funding criteria, suggesting that programs guided by specific political motives might hide significant benefit losses.

Payment for ecosystem services is vital to climate change mitigation, from reforestation efforts and activities to protect aquifers from groundwater intrusion to wetland expansions, carbon sequestration, and soil enhancement activities. Fei and McCarl discuss the critical role that agricultural soil can play in mitigating carbon, sequestration, and the technologies associated with soil and their potential role in reaching net zero.

Feeding the world and responding to climate change are mounting concerns our generation faces. We should use policy to help, but how? Articles published in this special theme can help elucidate the policy's role.

For More Information

Hochman, G., & Zilberman, D. (2021). Optimal environmental taxation in response to an environmentally-unfriendly political challenger. Journal of Environmental Economics and Management, 106, 102407.

Weitzman, M. L. (1974). Prices vs. Quantities. The Review of Economic Studies, 41(4), 477-491.

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Policy Durability: Taxes versus Standards

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In the realm of economics, efficiency is king. However, the influence of politics is undeniable: It shapes economic intuition and strikes a delicate balance between economic efficiency and political motives (e.g., Frieden, 2020). To further investigate this claim and shed new light on the topic, we delve into environmental policy choices within democratic regimes, taking a political-dynamic perspective. In doing so, we aim to illustrate how political economy may influence decision making when designing policy.

While economics focuses on the efficient allocation and distribution of resources (Nordhaus, 2019), it aims to maximize efficiency and overall societal welfare. Economic analysis helps identify trade-offs and quantify the costs and benefits associated with different policy options, evaluating the efficiency and effectiveness of policies. As a result, economists often advocate for policies that promote economic growth, market competition, and resource allocation based on market forces (e.g., Birdsall et al., 1993).

Nonetheless, political actors like governments and policy makers have diverse objectives, including maintaining political power and promoting their ideologies. Considerations of public opinion, electoral cycles, and power distribution often drive these political decisions (e.g., Canovan, 2002; Adams et al., 2004). Policy makers face trade-offs when making decisions, which may lead to compromises between different groups and adopting policies that may not align with economic efficiency.

Although politics and economics are distinct fields, they are interconnected and influence each other in various ways. Political economy stems from the realization that political entities run the world and studies how political and economic forces interact and influence each other (e.g., Drazen, 2002; Anderson, Rausser, and Swinnen, 2013; Grossman and Helpman, 2020). It explores how political institutions, policies, and interests shape economic outcomes.

Political factors can shape economic policies and regulations. At the same time, economic conditions and outcomes–such as unemployment and economic growth–can influence political dynamics and electoral outcomes. Understanding the interplay between politics and economics is crucial because it helps policy makers navigate the complexities of decision-making and formulate policies that consider both political feasibility and economic efficiency. Below, we discuss balancing political objectives and economic realities, emphasizing the importance of policy durability. Policy durability refers to the ability of a policy to withstand political changes and remain effective over an extended period, achieving long-term stability of the policy approach. We focus on stability and consistency in policy design, implementation, and outcomes, implying that the policy framework remains intact and functions effectively despite changing political landscapes.

The Political-Economic Environment

To help organize the discussion and identify the critical variables and their relationships with each other, we make the following assumptions on the underlying beliefs and premises of the political-economic environment guiding the policy choices. That is, we make four key assumptions underpinning policy choices that facilitate transitioning the regulated industry toward cleaner technologies over time.

We first start with the Putty-Clay hypothesis, assuming a fixed input-to-output relation in the short run (Johansen, 1972) but a more flexible one in the long run. In the long run, firms may adopt new (more precise) technologies that reduce pollution and conserve resources but require investments (Caparros, Just, and Zilberman, 2015). Second, we assume that policy makers utilize policy instruments to facilitate the transition to cleaner technologies, which often necessitates irreversible investments in equipment—sunk costs that, once incurred, cannot be recovered if policy makers reverse a policy decision. Once firms invest in cleaner equipment that requires a substantial financial commitment, they are more inclined to persist with cleaner technologies over time. For example, the California Air Resources Board imposed air quality regulation for decades, building technological capabilities, developing relationships with the state legislature, and increasing the number of those benefiting from the technology over time (Hanemann, 2008; Pahle et al., 2018). A policy initiated in the 1970s yielded coalitions supporting renewable energy manufacturing, installation, and renewable energy investments, which grew over time (Kelsey et al., 2013). Third, heterogeneity among firms, measured through the variability of the firms' technical coefficients, is inherent in any industry (Lyubich, Shapiro, and Walker, 2018), resulting in not all actors readily adopting new technologies to comply with environmental regulations. Some firms may choose to cease operations altogether. The fourth assumption, learning by doing, significantly reduces costs over time as firms gain experience and expertise in implementing cleaner technologies, reducing costs and thus making the cleaner technologies more economically viable in the long run (Way et al., 2022).

Basing the discussion that follows the above premise, we explore policy makers' policy choices over time, assuming a two-party democratic regime where one of the parties places more weight on the environment. We first focus on using a tax and how politics can lead to deviations from the economically efficient policy, such as the Pigouvian tax. The Pigouvian tax is a cost-efficient pollution tax. It aims to internalize the external pollution costs by taxing activities that generate negative environmental impacts. However, political considerations often influence the implementation and level of taxation. Next, we expand the policy choices faced by the incumbent government and delve into the selection of policy instruments, specifically the decision between taxes or standards. Here, we argue that political economy considerations are paramount in shaping the preference for standards over taxes.

The Optimal Political Tax Is Different from the Cost-Efficient Pollution Tax

Policy makers realize that they may not get reelected and that future governments may reverse their policy decisions. Thus, policy makers strive to design policies that tie the hands of future governments. Focusing on executive orders in the United States between 1937 and 2013, Thrower (2017) showed that reversing policy is costly and that the higher the cost of switching policy, the less likely the reversal is. By establishing frameworks that limit subsequent administrations' discretion, policy makers provide the certainty and stability necessary for long-term planning and investment in cleaner technologies. Balancing the desire for reelection with the desire for a lasting legacy becomes a delicate task in shaping effective and enduring tax policies.

The framework highlights policy makers' craftsmanship of policy durability, referring to the ability of a policy to remain in effect and maintain its intended outcomes over an extended period. Policy durability encompasses a policy's stability, longevity, and resilience in the face of potential changes in political circumstances. The incumbent, pro-environment government enhances policy durability by providing a formal framework more resistant to immediate changes in political leadership.

The importance of policy durability in Western democracies striving to transition to cleaner technologies shows that uncertainty regarding future governments yields a higher pollution tax than otherwise—a pollution tax that is higher than the tax chosen when assuming no political uncertainty. Incumbent governments respond to political uncertainty by implementing policies incentivizing the early use of clean technologies (Hochman and Zilberman, 2021). Real Option Value theory predicts that, given irreversibility and uncertainty about demand and supply, firms will delay decisions involved in capital-intensive investments (e.g., Arrow and Fischer, 1974). However, we show the opposite to be true under political uncertainty. Political uncertainty leads governments to incentivize the early use of technologies. The pro-environment incumbent government favors policies that place more weight on the early adoption of cleaner technologies than those chosen by a central planner aiming to maximize social welfare.

However, it is essential to note that policy durability is not guaranteed. Political, economic, or social shifts can challenge the continuity of policies. Changes in political leadership, shifts in public opinion, or financial crises can lead to the reevaluation or even the abandonment of policies. Maintaining policy durability requires ongoing efforts to navigate changing circumstances, build coalitions, and adapt policies to new challenges while preserving their core objectives.

Dynamics and Policy Design

The dynamics of policy design over time require policy makers to navigate a complex landscape of policy instrument selection, where we limit the discussion to the factors affecting decisions over time. That is, we define dynamics over time. While considering the strengths and limitations of various instruments, politicians select the most appropriate for achieving the desired political outcomes, leading to an exciting trade-off over time when comparing a tax to a standard.

There are numerous successful examples of governments mandating technological change, including substitutes for chlorofluorocarbons (Ashford et al., 1985; McFarland, 1992), flue gas desulfurization systems for SO2 control in the power sector (Popp, 2003; Taylor et al., 2005), and automobile emissions (Lee et al., 2010). Other examples also led to government intervention and include concerns about climate change and the environment (Rajagopal et al., 2007; Collier, Conway, and Venables, 2008; Hellegers et al., 2008; Maibach et al., 2008; Bulte and Damania, 2008, among many others), food security and resilience (Upton, Cissé, and Barrett, 2016), and the agricultural sector's economic viability (Sunding and Zilberman, 2001; Spicka et al., 2019). However, the economic literature usually criticizes the mandating of technological change, objecting to the effectiveness of command-and-control (Jaffe et al., 2002; Bansal and Gangopadhyay, 2005) and arguing that firms are often unclear on the cost of compliance (Miller, 1995; Kemp, 1997; Gerard and Lave, 2005) and the regulators' ability to enforce regulations (Lutz et al., 2000; Bansal and Gangopadhyay, 2005; Gerard and Lave, 2005; Mohr, 2006; Puller, 2006; Mickwitz et al., 2008). Although economists advocate for market incentives like a carbon tax, most of the policies ushered were through regulations and subsidies (Goulder et al., 1999).

Nonetheless, from a political perspective, using standards in the short run can provide distinct advantages over taxes, especially in transitioning industries toward cleaner technologies. The standard achieves a given pollution target with more employment than a tax. We extended Hochman and Zilberman's (2021) framework and concluded that policy makers opt for standards when advanced technologies are not readily available. By mandating specific equipment and practices, standards require investments that lead to irreversible outcomes. Once stakeholders commit to these investments, they are more likely to adhere to the standards. To this end, if both the standard and the tax lead firms to adopt the same pollution control technology, then a standard is preferred by the firms where the tax burden causes firms to exit in the long run and the surviving firms become more spatially concentrated (Wu, Segerson, and Wang, 2022).

When considering the choice between implementing taxes or standards as policy instruments, it is essential to understand the dynamics and implications of each approach. While taxes, such as Pigouvian taxes, aim to internalize the external costs of pollution by imposing a financial burden on activities that generate negative environmental impacts, they incentivize firms to reduce emissions or adopt cleaner technologies to minimize the tax burden and encourage cost-effective pollution reduction. On the other hand, standards set specific requirements or limits on emissions and pollution levels or technological specifications that firms must meet, driving the adoption of cleaner technologies by mandating specific equipment or practices. Thus, regulation encourages irreversible investments in cleaner technologies. Standards achieve this goal while having less of an impact on employment than a tax would (Hochman and Zilberman, 1978).

We argue that the choice between taxes and standards is not a one-size-fits-all decision and depends on various factors, including the specific context and stage of technological development, and that political economy considerations often come into play in this choice. When advanced clean technologies are not yet widely available, standards that require irreversible investments may be more effective. The initial cost of adopting cleaner technologies may reduce short-term profits. Still, the commitment to these investments promotes long-term adherence to the standards with a lower employment price tag. However, as technology advances and adoption rates increase, financial incentives such as taxes may become more viable. Over time, larger coalitions supporting the transition to cleaner technologies can influence the political landscape, making it easier to implement a tax policy as firms have more economically viable alternatives.

Policy Choices

To understand better policy choices and their effect on adoption rates, we introduce two terms, intensive and extensive margins. Intensive margins refer to the level of effort or investment per unit of output of an active firm. In contrast, extensive margins refer to the change in the overall production level due to new firms entering the industry or other firms becoming idle and exiting the industry. Environmental policies, taxes, and standards can affect the intensive and extensive margins differently. A tax on emissions, for example, would increase the cost of production and reduce the profit margin per unit of output, encouraging firms to reduce their production levels and lower the extensive margin. When firms can invest in cleaner technologies, the tax would incentivize them to invest in technologies that reduce emissions and improve efficiency, which would increase the intensive margin. On the other hand, standards would require firms to meet a specific emissions target or efficiency standard, which may incentivize firms to invest in cleaner technologies to meet these standards. However, it may also force firms to exit the industry. To this end, under a broad and plausible set of conditions (Hochman and Zilberman, 2023), the standard’s effect on forcing firms to exit the industry is more pronounced than the effect of a tax.

The differences between a tax and a standard affect the choice of the policy instrument over time. The dynamics of technological change and uncertainty about political outcomes lead the pro-environmental incumbent government to select stricter policies, thus increasing the adoption of capital-intensive technologies and establishing results that are difficult to reverse. Although in the short run, when conservation and abatement technologies are either unavailable or in their infancy with only the prototypes and pilot projects introduced, the standard is preferred to a tax from a political vantage point, even though efficiency strongly recommends using market-mediated policies such as a carbon tax. However, as innovations yield more conservation and abatement technologies, taxes also become the preferable policy from a political-economic perspective.

The analysis suggests using standards to control pollution, especially at the early stages of regulation, and emphasizes investment in research and development (R&D) to develop abatement technologies. Besides, the research indicates a transition to pollution taxes likely in the long run when new cleaner technologies are more effective. Crucial from a political-economic vantage point is the ushering of policy that minimizes effects leading to reducing the industry's capacity yet achieving the needed switch to cleaner technologies with less loss in employment and consumer welfare.

Concluding Remarks

This article highlights the importance of introducing technological innovations that enable modifications of existing assets. Societies with infrastructure capabilities that can develop technologies that allow fixed asset changes will have lower costs over time and experience less difficulty when introducing environmental regulations. For example, policy design should consider advancements in information technologies and harness these technologies to introduce precision technologies that can reduce pollution emitted by existing units (Khanna and Zilberman, 1997). Precision technologies reduce waste and minimize agriculture's environmental footprints, thus alleviating environmental degradation. Some examples of precision technologies include precision sprays and weeding robots. These technologies may lead to a less painful transition to a greener economy. These concepts also address other considerations, such as providing credit incentivizes investment in new technologies and their adoption in the early stages of development, thus enhancing learning by doing. The diffusion of the technology that supports the advancement of new conservation technologies needs to subsidize R&D and incentivize adoption to become socially impactful (Zilberman et al., 2022).

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Understanding Supply Chains Is Crucial for Good Agricultural Policy

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Keywords: Agricultural Policy, Innovation, Supply Chain

Introduction

Agricultural economists recognized long ago that agriculture and the food sector have high rates of innovation, with new products and technologies emerging continuously. Further, an increasing percentage of the value of food and other farm-grown products is generated outside the farm gate (Cochrane, 1979). The transition from ideas for new products to the actual goods and services utilized by consumers is through multiple supply chains that evolve and intersect over time. These supply chains include multiple institutions (like firms, farms, and universities); understanding the design of agricultural and other policies requires understanding the forces that affect the performance of supply chains. In this paper, we introduce two major types of symbiotic supply chains—innovation supply chain and product supply chain—and analyze some of the factors that affect their performance, discuss how supply chains evolve considering recent events, and assess how supply chain considerations should affect policy interventions.

Innovation and Product Supply Chains

New products and services originate from an idea. This can be a scientific discovery with a practical implication, a realization of a new need, a marketing-driven product development for which the firm needs to promote demand, or an improvement in existing technology. The transition from the idea to an implementable innovation occurs in the innovation supply chain. We identify three types of innovation supply chains: First, the *educational-industrial complex*, where university scientists may make a discovery that could lead to supply chain innovations. Frequently, it is further tested and developed by applied researchers in experiment stations and extension units In other cases, it is developed by private companies (start-ups or major corporations) that acquire the right to obtain a technology through offices of technology transfer. Second is *recombinant innovation*, where a practitioner or entrepreneur develops a new idea and modifies existing technologies to develop a product or service. Third is *relentless innovation*, where companies constantly improve their existing product. The development of modern agricultural biotechnology is an example of the educational-industrial complex in action. The discovery of DNA led to further research on which genetic material influenced certain aspects of performance (yield, drought tolerance). Companies use this knowledge to develop new products. Farm and irrigation improvements have frequently resulted from recombinant innovation, where companies modify technologies from the automobile and oil industries to produce new farm machinery and irrigation equipment. Relentless innovation improves food products, agricultural crop varieties, pest control techniques, and machinery. For example, precut salads have improved over time to include multiple greens and dressings and to have a longer shelf life (Lugg, Shim, and Zilberman, 2017).

Implementable innovations are developed into commercial services and products sold and utilized by consumers through multistage product supply chains. Each supply chain has a hierarchy, starting with an upstream, going through midstream, and then downstream. At each stage, there may be several levels. For example, it is helpful to consider the input suppliers who provide the seed and farm equipment upstream of the food supply chain in the United States. Further, inputs have their own supply chain, so we emphasize the symbiotic relationship between input and output supply chains (Reardon and Timmer, 2012). Farms and ranches are the midstream in the production of food. The downstream has several levels: processors, wholesalers, and retailers. In earlier periods in U.S. history, many agricultural products were introduced by migrants who moved from Italy to California. Later, agricultural scientists and extension specialists developed new varieties appropriate for specific soil and climatic conditions (Cochrane, 1979). In 2021, the farm share was only 14.5% of the total food expenditure

(USDA, 2022). Some of the new agricultural products were introduced by organizations that became intermediaries. Biofuel supply chains were induced by regulations subsidizing and mandating the use of biofuels and, frequently, investors in refineries were managing the supply chains. They contracted the farmers to grow the feedstock and sold the biofuel to the oil companies and other byproducts (e.g., dried distiller's grains, DDGs) to feed distributors. The organization that introduced prepackaged salads and baby carrots concentrated on processing the carrots and other vegetables that, to a large extent, they contract others to grow (Zilberman et al., 2023).

The Operation of Supply Chains

Entrepreneurs who design product supply chains to implement innovations may start by assessing demand, maybe through marketing research, and then develop a strategy that makes financial sense and aim to pursue net discounted profits, adjusted for risk (Reardon et al., 2021). The plan must determine how much, what, and where to produce in each period, the extent to which internal resources (vertical integration) or others (through contracts or markets) should be relied upon, how much to invest in each period, and what output quantities to market at different locations. Introducing technologies requires adaptive learning, and entrepreneurs may modify their plans as they go. They are constrained by market demand, human capital and knowledge, regulation, and financial considerations. The performance of the supply chain is affected by dynamic processes of learning by doing (the reduction of the cost of production as knowledge accumulates); learning by using, which increases demand for the product; imitation, which may increase both supply (new entrants) and demand; and actions of competitors, which may reduce demand. Further, the design choices are shrouded in uncertainty. Therefore, managing a supply chain is an adaptive exercise in which plans are modified over time in response to learning and reality.

Supply chains will likely start production and marketing in the most favorable locations and extend their reach and product mix. After McDonald's got its start in California and the Midwest, where the company refined their product and business model, it spread throughout the United States to Europe and then the rest of the world. Tyson Foods started shipping chicken from Arkansas, moved to providing chicks to contractors, and processed them to sell throughout the United States. They expanded their product mix to include processed chicken and then moved to other livestock, establishing subsidiaries globally. Gallo started as a small winery in Modesto, California, developed new methods (steel barrels) to increase efficiency, and increased their product mix and marketing network. They still grow grapes but contract with other farmers for most of their grapes.

Finance and marketing are crucial in designing and managing supply chains. Most entrepreneurs must raise funds for investments and ongoing operations, and potential lenders may not provide the requested amount. So, financial constraints may shape the design of the supply chain. The precut salad was initiated by a large lettuce producer (Bruce Church), who sold all his land to finance the processing activities. As enterprises grow and expand geographically, they establish partnerships to obtain local knowledge and new sources of finance. Similarly, marketing analysis is crucial in product design, pricing, and location selection. MARS Inc., a large producer of dog food, has invested in assuring their products are palatable to the dog (since if your dog doesn't like the food, you will switch to another brand). Finally, supply chain design is responsive to policy situations: Reduced interest rates are likely to increase investments, locations that provide preferential treatment will be more attractive for investment, and regulatory uncertainty may reduce the likelihood of investment and deter entrepreneurship. Uncertainties about agricultural biotechnology regulation have led to significant underinvestment in the industry (Zilberman, Reardon, et al., 2022).

The Evolution Pivoting and Adjustment of Supply Chains

Our supply chain perspective has some implications for economic analysis. First, it suggests that goods, markets, and trading arrangements are endogenous. Innovation in supply chains leads to the emergence of new goods and services, which require establishing supply chains that lead to the emergence of markets and other mechanisms of exchange. As products become more differentiated and have detailed specifications, spot market transactions are replaced by contracts. In modern industries like computers, companies like Apple have established contracts with suppliers that detail product specifications, prices, time of delivery, etc. Such developments are likely to occur in the agri-food sector as it evolves. Broilers, eggs, and—to some extent—hogs already have high contracting levels. Use of contracts is increasing in fresh fruits and vegetables and may increase in other sectors with more precise product specifications.

Second, new agricultural industries are not perfectly competitive. The patent system provides innovators with intellectual property rights and monopoly powers. Companies that anchor supply chains have market power, resulting from patents, trade secrets, or scale both in their input and output markets. Over time, as new innovators enter, they introduce competing products and establish their own supply chains. As a result, the industrial structures become monopolistically competitive. Namely, several firms could be competing on similar products, but each has some market power. For example, several competing fast-food chains have somewhat unique products. Still, each has significant market power, although that power is constrained given the availability of close substitutes. The market power of incumbent firms is reduced, and competition is enhanced when there are fewer barriers establishment of new supply chains and organizations and entry into markets (Reardon et al., 2021).

Supply chains are living organisms that adapt to changes and shocks. The recent pandemic provides many examples. Social distancing regulations, as well as restrictions on travel, led to drastic changes in agri-food supply chains. Digitization of the food system has been promoted but has proceeded slowly. The pandemic accelerated this digitization. In particular, e-commerce adoption increased by 70% in India and 80% in Mexico in 2020 (Reardon et al., 2021). In China, online orders quadrupled during the pandemic. The food delivery sector expanded worldwide, many retailers started providing delivery services, and direct sales from farmers or processors to consumers expanded (Reardon et al., 2021). Restaurants that pivoted to emphasize takeout survived and thrived during the pandemic, and others failed (Reardon et al., 2021). The farming sector adapted to labor shortages and supply bottlenecks through automation; modification of production, harvesting, and processing procedures and sources of labor; and innovative marketing (Kaplan, Lefler, and Zilberman, 2022). The adjustment to the pandemic is one example of supply chain adaptation. Water supply chains have adapted to increased demand and shocks like drought by developing physical infrastructure like storage, new technologies like drip irrigation, and introducing institutions like water trading (Zilberman, Huang, et al., 2022). In these cases, adaptation has involved interaction between innovation, product supply chain, and policy makers. California's 1987–1991 drought accelerated the modification of drip irrigation to fit a larger set of California crops and to expand the network of irrigation dealers, which contributed to increased adoption of the technology and led to the introduction of water banking, which enabled saving much of the fruit and vegetable production in the state (Zilberman et al., 1994).

A supply chain perspective is essential when considering the impact of climate change on agriculture. Most of the literature emphasizes the direct effect of climate change on the farm. Climate change may affect food supply chains by affecting production regions, input supply sources, and market access capacity. If a farming region loses access to a port or a road connecting them to the rest of the world, its ability to export its food or obtain inputs is limited and may cause significant harm. Similarly, consumers may be affected by climate change, not because of a reduction in food production but lack of access. Reardon and Zilberman (2018) suggest that climate change concerns may cause some retailers to increase redundancy and rely on multiple suppliers, expanding inventory, and purchasing options to obtain extra supply. Climate change concerns, thus, enhance the value of increased resiliency of the supply chain (Reardon and Zilberman, 2018).

Policy

Economic policy analysis should recognize the importance of supply chains and their evolution and behavior. Our analysis suggests several important policy implications.

Public Investment in Research, Education, Extension, and Cyber-Infrastructure Is Essential

As we have seen, the educational-industrial complex, the source of many substantial innovations, leads to the establishment of new products and the emergence of new supply chains. Academics are part of the entrepreneurial environment and play a key management role in start-ups that lead to new industries. Students in land grant and other universities are the future entrepreneurs who create continuous industrial renewal (Graff, Heiman, and Zilberman, 2002). One question is whether the decreasing ratio of public versus private investment in agricultural research over time has or will have negative implications for agricultural productivity growth, given that public research may have a comparative advantage in foundational research (Clancy, Fuglie, and Helsey, 2016).

Academic research is essential for other reasons. New industries and supply chains may generate externalities regarding pollution and health effects. Private sectors do not have the incentive or capacity to investigate these implications. Governments need the capacity to regulate industries, assure consumers that their food is safe and protect the environment. Knowledge created by academic research is crucial for these purposes.

Further, research and education are crucial to establish the bioeconomy. Humanity is facing the combined challenges of climate change, loss of biodiversity, and food insecurity. With the modern tools of biology and information technologies, natural resources in agriculture can be expanded to establish the bioeconomy, where agriculture and natural resources will produce much more than food. In the bioeconomy, using modern knowledge, agriculture will produce food, fuel, and chemicals and enhance the transition from nonrenewable reliance on fossil fuels to a renewable economy (Zilberman et al., 2018; Wesseler and von Braun, 2017).

Historically, the government's role in maintaining and developing supply chains has been to provide or assure the provision of goods that would allow the emergence of new industries that will improve human welfare and lead to sustainable development. That includes investment in public goods like research, education, and other infrastructure needed to develop new modern sectors. One key element is ensuring accessible and affordable cyber-infrastructure that will enable connectivity to the internet and the web throughout the country and would otherwise hamper the capabilities of rural regions to contribute to the bioeconomy and upscaling of agriculture.

Incentives for Socially Desirable Activities

Innovations are commercialized and developed when individuals have incentives to pursue them. Addressing climate change and other problems will require creative solutions and new industries. Research is essential for finding solutions, but the development of supply chains for industries that implement these solutions requires that investors will expect to be rewarded for their efforts. Thus, policies like carbon taxes can trigger both research and new industries that will reduce greenhouse gases. However, when such policies are politically infeasible, it may be necessary to pursue alternative strategies, such as subsidizing green technologies, regulating polluting activities, or providing credit to implement green innovation.

Acceptance of Nonmarket Exchanges and Wise Regulation of Market Power

As we have seen, new innovative sectors frequently have noncompetitive structures where the entrepreneurs that implement an innovation make monopoly profits. Further, supply chains that introduce new products or technologies may rely on contracting or may be vertically integrated rather than rely on competitive market transactions. Accepting this reality is important and attempts to enforce competitive markets and reduce the profitability of investment in new industries may retard innovation. At the same time, there is a place for anti-trust policies that regulate against arrangements that limit entry to industries and restrict choices. Investment in public goods and in research that will lead to innovation—as well as the development of mechanisms (including the provision of credit and other support) to support new entrants and new entrepreneurships and protect them against sanctions by incumbents—will be important to maintain well-functioning and innovative sectors and economy.

Conclusion

Addressing the challenges of climate change and food security will require the introduction of innovations and the establishment of supply chains that will be the foundation of a bioeconomy that will utilize new knowledge in the life sciences and natural resources to produce renewable and clean alternatives to products produced by nonrenewable and greenhouse gas-emitting industries. New innovations are developed into commercial products through the innovation supply chain, and these products are implemented through the product supply chain. Applied economic research should emphasize research on supply chain and can play an important role in the design of policies that would lead to improved research direction and the establishment of new, well-functioning industries.

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CHOICES

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Uncovering the Impacts of Steel Tariffs on the Canned Foods Sector: Reevaluating Trade Policy Winners and Losers

Andrew Muhammad and Carlos J.O. Trejo-Pech

JEL Classifications: F13, Q11, Q17
Keywords: Canned foods, Steel, Tariffs, Trade war

Producers and users of steel are a perfect example of competing special interests: Both groups have lobbied the government on behalf of their sectors, respectively arguing for and against the tariffs on imported steel imposed by the Trump administration in 2018. One group on the "against" side is the U.S. canned food sector, which has relied on imported tinplate (tin-plated steel) for production. Tin-plated steel has been subject to both tariffs and quotas since 2018. In this article, we explore the impacts of these tariffs and their implications for canned food prices and domestic food security.

Economists are more likely to argue for complete trade liberalization (i.e., free and open trade) than for the protectionist policies favored by President Trump. As noted by Friedman and Friedman (1997), "Ever since Adam Smith there has been virtual unanimity among economists, whatever their ideological position on other issues, that free trade is in the best interests of trading countries and of the world." However, arguments for trade liberalization are often framed in the context of *producers* versus *consumers*, where protection benefits special interests (producers) at the expense of the broader, general interest of society. Consequently, protectionism is often viewed through the concentrated benefits/diffused costs lens, where the concentrated group (i.e., producers) has far more incentive to lobby for protection than the diffused group (i.e., consumers) to lobby against it. However, this does not fully apply to specific trade actions where there are competing special interests and concentrated gains (or losses) and lobbying efforts on both sides of the issue.

The current tariff situation and lobbying efforts of the U.S. canned food and steel sectors provide an ideal case for examining trade protections in this context (i.e., competing special interests). In the United States, the canned food sector was valued at an estimated $17.8 billion in 2019 (Statista, 2023), with tin-plated steel being the primary packaging material. The data suggest that the impacts of the section 232 tariffs on the canned food sector have not been negligible. However, more research is needed for a more quantitative assessment of their impacts and implications.

Background

During his time in office, President Trump advocated for greater trade protections, imposing tariffs on a broad range of products. In March 2018, President Trump signed a proclamation to impose a 25% tariff on all imported steel, based on a Department of Commerce report that indicated that imports had the potential to threaten U.S. national security. Section 232 of the Trade Expansion Act of 1962 allows the president to use trade barriers for national security concerns (The White House, 2022). A major concern was the unprecedented growth in China's crude steel production, which exceeded 1 billion metric tons in 2020, accounting for more than half of global production. Note that the next highest country (India) produced around 100 million metric tons and the United States produced around 70 million metric tons (World Steel Association, 2022). While higher prices via import quotas and tariffs benefited the U.S. steel sector, the negative impacts on downstream steel-consuming companies exceeded any gains. For instance, 75 times as many jobs were estimated to have been lost in downstream steel-consuming sectors compared to jobs gained in the steel-producing sector (Russ and Cox, 2020).

Food canning can be traced back to the 18th century in France, and the basic principles have not changed significantly since. Clearly, the direct benefit of canning is food preservation, in that the process allows for converting perishable food items into shelf-stable food, allowing for quality and nutritional properties to be maintained for years after being processed (Canned Food Alliance, 2023). The long-lasting nature of canned foods reduces food waste, common for fresh and perishable food items. Food waste and loss—caused by many factors from the farm through the final consumer and representing 30%–40% of the food supply—is a problem because a significant amount of food is sent to landfills, which also contributes to greenhouse gas emissions from activities prior to and during disposal (U.S. Department of Agriculture, 2023).

Food preservation and convenience make canned foods suitable for food security in times of crisis, such as natural disasters or pandemics. For instance, at the beginning of the COVID-19 pandemic, households could secure food by increasing canned food purchases when restaurants were in lockdown and trips to grocery stores were less frequent (Hillen, 2021; Pigott, 2022). Unfortunately, the steel tariffs lasted throughout the pandemic, a time when consumers would have benefited from relatively lower prices for shelf-stable food items. As discussed in the next section, canned food prices significantly increased after the steel tariffs were imposed in 2018, exceeding overall inflation in recent years.

U.S. Steel Tariffs and the Canned Foods Sector

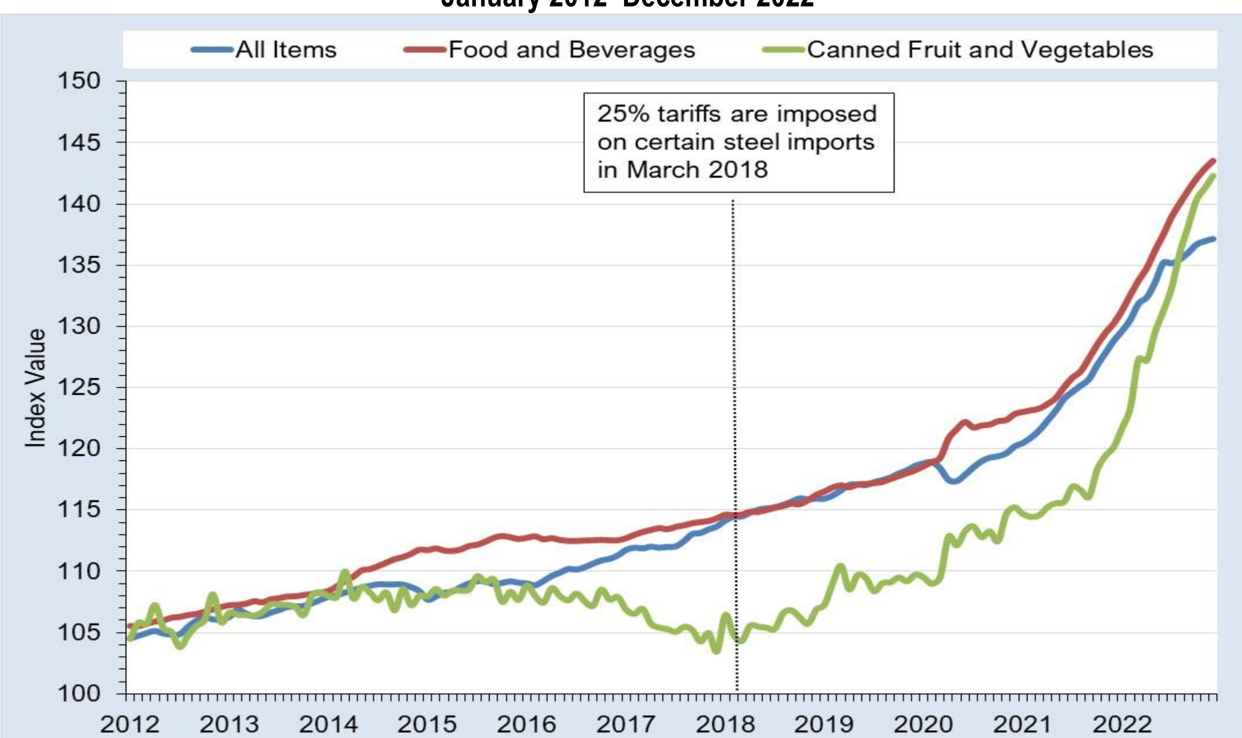
It was fitting that when the steel tariffs were first introduced, then-Commerce Secretary Wilbur Ross used a canned food item to defend the tariffs, suggesting a negligible impact on consumers and prices. In 2018, Secretary Ross noted (Horowitz, 2018),

> *This is a can of Campbell's soup, there's about 2.6 cents, 2.6 pennies, worth of steel. So, if that goes up by 25 percent, that's about six-tenths of one cent on the price of the can of Campbell's soup.*

Interestingly, canned food prices increased by more than Secretary Ross speculated they would. We asked the CEO of a U.S. canned food company why have prices increased significantly more than "six-tenths of one cent." He indicated that due to the tariffs, companies were paying significantly more for cans for several reasons. First, he noted the difficulties in transporting empty cans: shipping empty cans is tantamount to shipping air. Therefore, can manufacturing should be as close as possible to canning facilities. Import restrictions and tariffs make purchasing steel and producing cans more difficult, causing canned food companies to contract with can production facilities at greater and greater distances. Additionally, tinplate makes up a small share of U.S. steel production, and there is limited capacity to expand. This limited capacity has resulted in regional market power, allowing for higher mark-ups and putting additional upward pressure on prices.

To better understand how the steel tariffs might have affected canned food prices, we examined the consumer price indices for all items (CPI), food and beverages, and canned fruit and vegetables over the last decade

Figure 1. Consumer Price Indexes for All Items, Food and Beverages, and Canned Fruit and Vegetables, January 2012–December 2022



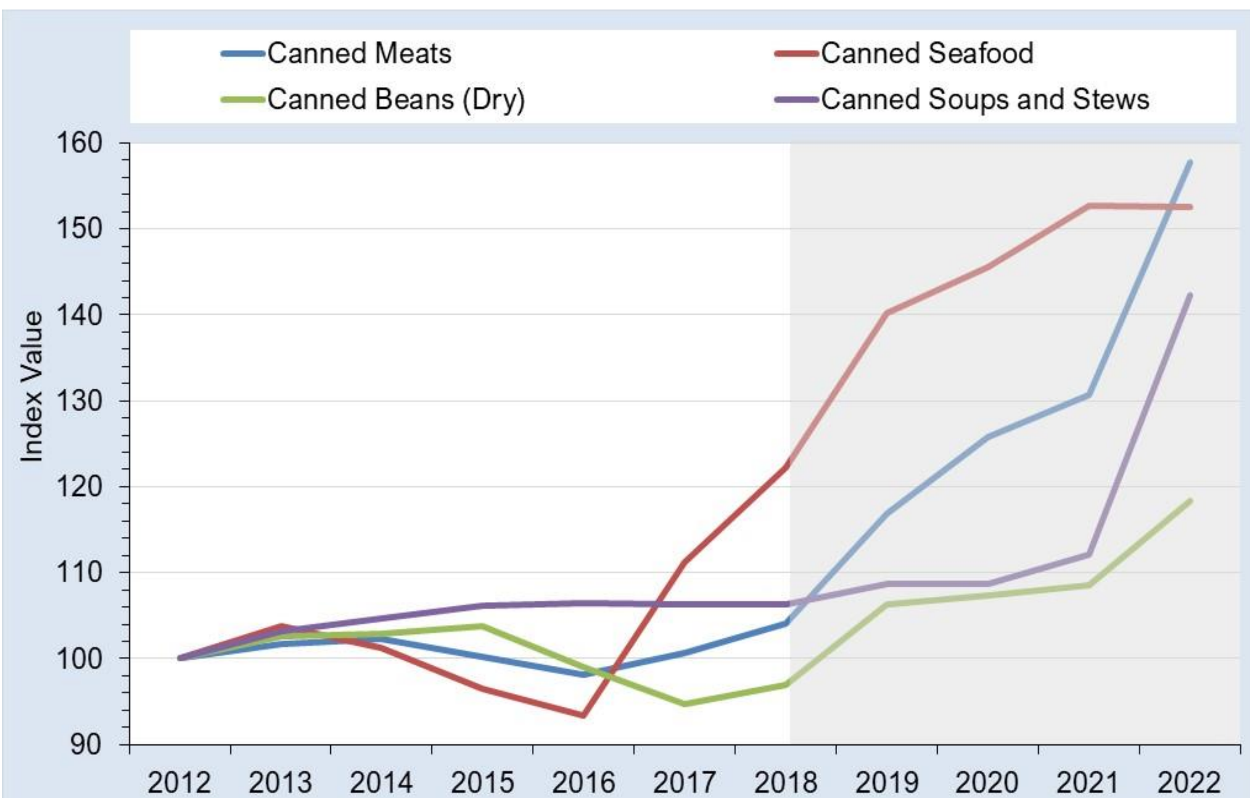
Note: Index values are the U.S. city average and seasonally adjusted. The indexes were rescaled based on the 2010 monthly average for comparison purposes.

Source: Bureau of Labor Statistics (2023).

(January 2012–December 2022) (see Figure 1). If the steel tariffs were inconsequential, then it could be argued that canned food prices would have followed a similar pattern as the CPI or food prices overall. Interestingly, the canned fruit and vegetables price index decreased from 2015 to 2018, even as the price indices for all goods and food and beverages increased. Even more interesting, the canned fruit and vegetables price index persistently declined right up to the point when the steel tariffs were imposed in March 2018, suggesting that the steel tariffs resulted in relatively higher canned food prices. Since the COVID-19 pandemic also caused prices to rise, Figure 1 might be capturing both the effects of the pandemic and the tariffs. However, the relatively faster price growth and the increase during 2018 and 2019 are likely due to the steel tariffs. Note that similar patterns occurred for other canned foods. Figure 2 shows the producer price indices for canned meats, seafood, beans, and soups and stews. Although canned seafood prices were rising before 2018 and the price of canned soups and stews did not significantly increase until 2022, both canned meats and canned bean prices (at the producer level) followed a similar pattern as the price index for canned fruits and vegetables: steady or decreasing prices until 2018, followed by a persistent upward trend thereafter. This provides even further evidence that the steel tariffs increased canned food prices.

Last, we considered U.S. tin-plated steel imports since 2012, as defined by three Harmonized System (HS) categories (72101200, 72121000, and 72101100) (see Figure 3). The Netherlands, Germany, and Canada supply a major share of U.S. tinplate imports, but South Korea and China also account for a significant share. The data show that imports were trending upward until 2018 and then declined and remained low throughout 2020. Compared to 2017, U.S. tinplate imports during this three-year period (2018–2020) were down 19% overall and down 35% for imports from South Korea, 23% for Germany, 15% for China, 13% for the Netherlands, and 9% for Canada. The relatively smaller decline in imports from Canada could be due to their tariffs being lifted in 2019. Interestingly, imports have fully recovered in recent years, which could be due to the United States and European Union reaching an agreement that converted the steel tariffs to tariff-rate quotas (Fefer, 2021). Is it important to note that Figure 3 includes tin-plated steel for all uses, so it is not clear whether the recovery in imports benefited the canned food sector specifically.

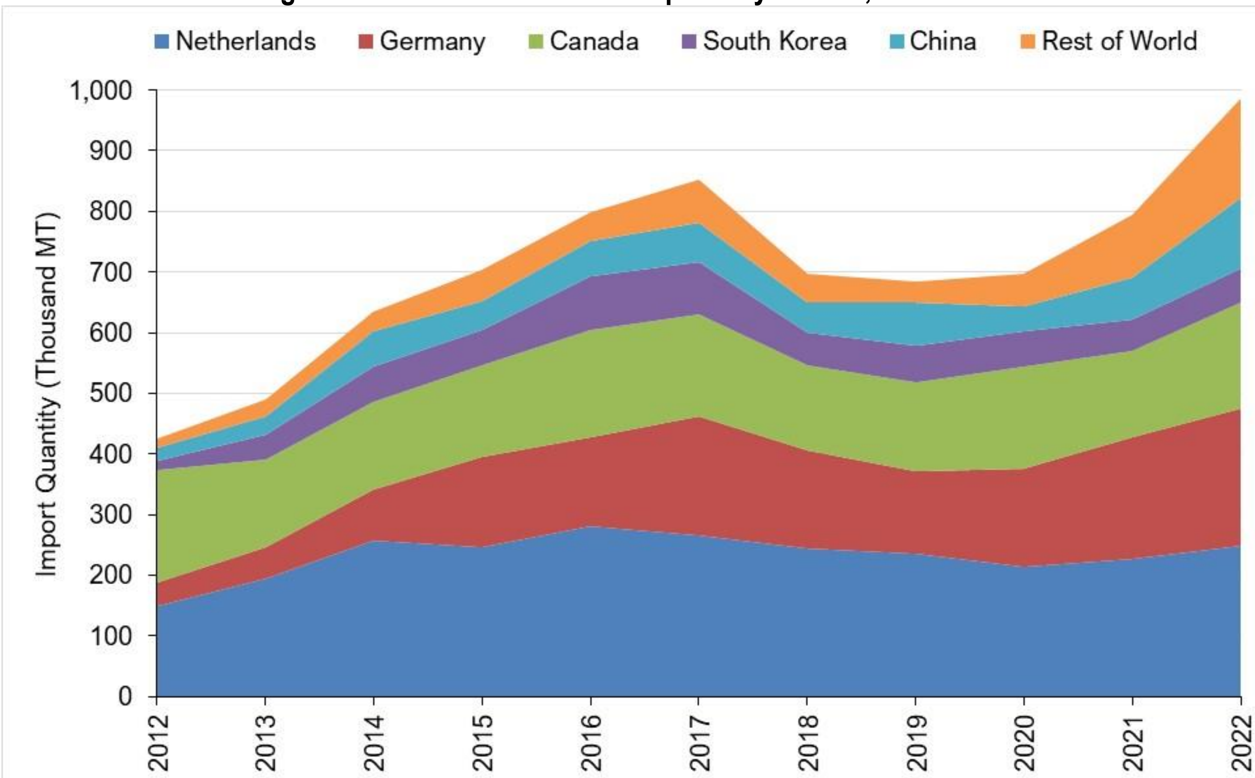
Figure 2. Producer Price Indexes for Select Canned Food Items, 2012–2022



Note: Index values were rescaled to 2012 for comparison purposes. Shaded area denotes the period when the steel tariffs were imposed.

Source: Bureau of Labor Statistics (2023).

Figure 3. U.S. Tin Plated Steel Imports by Source, 2012–2022



Note: Imports are an aggregation of the following Harmonized System (HS) categories: 72101200 *Iron/nonalloy steel, width ≥ 600mm, flat-rolled products, plated or coated with tin, less than 0.5 mm thick*, 72101100 *Iron/nonalloy steel, width ≥ 600mm, flat-rolled products, plated or coated with tin, thickness ≥ 0.5 mm*, and 72121000 *Iron/nonalloy steel, width ≤ 600mm, flat-rolled products, plated or coated with tin.*

Source: U.S. International Trade Commission (2023).

Closing

Producers in the U.S. canned food industry compete on price, making the industry one of the lowest-margin sectors (Wood, 2023). Thus, the proclamation by President Trump imposing 25% tariffs on imported steel caused concern for the canned food sector. The data in this study show that sector was likely impacted beyond the negligible expectations of the previous administration. This was in part evidenced by the relatively larger increases in canned food prices since 2018 compared to overall food prices and inflation. Downstream industries like the canned food sector that faced steel tariffs experienced declines due to higher production costs, decreased profits, and even decreased sales due to higher prices. However, a more quantitative assessment is needed to assess the degree to which all of these have occurred.

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Optimal Design of Climate-Smart Policy for Agriculture: Economic Principles and Political Considerations

JunJie Wu

JEL Classifications: Q18, Q28, Q58
Keywords: Agri-Environmental Programs, Climate-Smart Policy, Conservation Programs, Conservation Targeting, Farm Bill.

Many countries implement policies to address farming-related conservation issues such as soil erosion reduction, water quality protection, and soil carbon sequestration for climate change mitigation (Salzman et al., 2018). These policies are often referred to as conservation programs or agri-environmental policies (Baylis et al., 2022). Incentive schemes are typically built into these voluntary programs to encourage participation. Under such schemes, farmers often receive payments in exchange for adopting conservation practices or engaging in climate-smart activities. Such payments are often called payments for ecosystem services (PES) or green payments.

PES is not a new idea, but it is perhaps even more relevant today than in the past, partly because both public and private expenditures on ecosystem services have increased significantly over the years (Figure 1); this trend will likely continue given the potential role that PES could play in building resilience to climate change (Rausser and Zilberman, 2023). For example, the Inflation Reduction Act (IRA), signed into law by President Biden in August 2022, provided an additional $19.5 billion to support the USDA's conservation programs, including $8.45 billion for the Environmental Quality Incentives Program and $3.25 billion for the Conservation Stewardship Program (USDA, 2023). The European Union has historically spent considerably less on agri-environmental programs but has tripled its conservation expenditure since 2007 (Hodge, 2014; European Commission, 2023).

The rapid increase in conservation spending is by no means coincidental. There is broad public support for such programs. To farmers, PES is a new way of securing farm income support. To environmentalists, it is a new way of securing resource conservation and environmental protection. For many NGOs and international organizations, it is a new way of fighting poverty. To others, it is a new way of preserving the status quo of farm income support. Because of the broad support, conservation expenditures will likely continue in the future.

With increasing public expenditures on conservation, several issues have been raised, including:

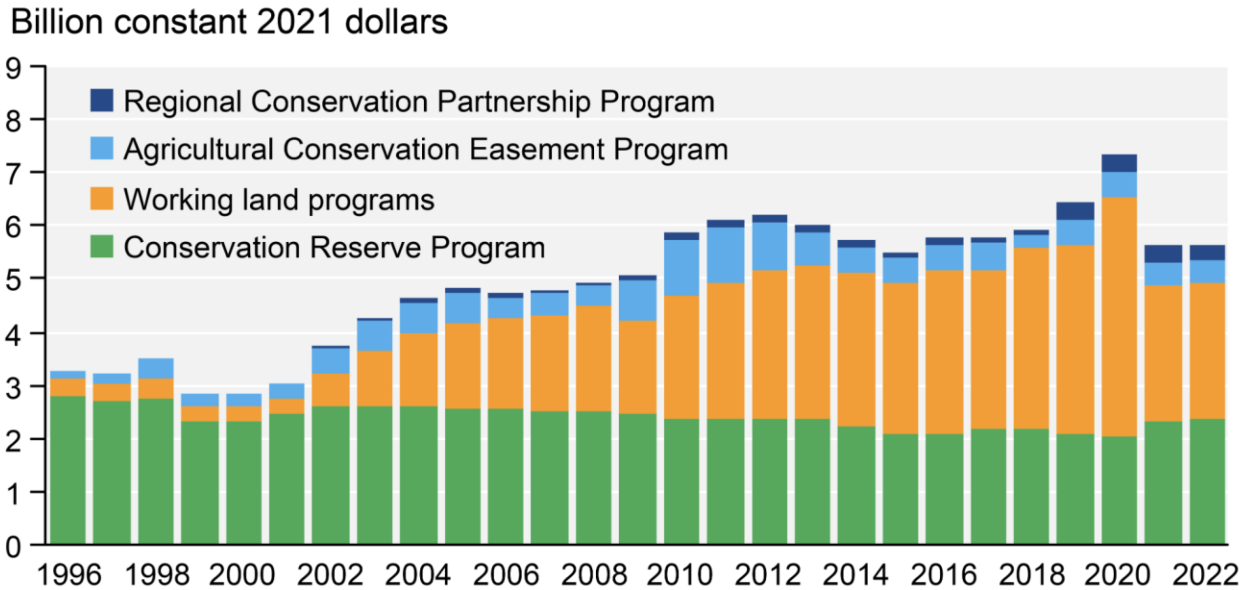
- How should conservation funds be allocated among different geographic areas or jurisdictions?
- Within a given geographic area, what criteria should be used to target resources for conservation?
- Should payments be based on adopting certain conservation practices (e.g., establishing riparian buffers or no-till practices) or some measures of environmental benefits (e.g., improved water quality or increased fish production)?
- How should the government deal with the additionality issue (i.e., farmers may demand payments for conservation practices that they would adopt anyway)?
- What are the distributional implications of alternative conservation targeting strategies?
- If poverty reduction is a policy goal, what are the most effective targeting criteria for achieving this goal?

In this article, I first describe several commonly used criteria to target resources for conservation and then discuss their environmental and political economy implications. Finally, I discuss the challenges of designing a truly efficient conservation program and propose an approach to addressing those challenges.

Targeting Conservation Efforts

Policymakers have many options at their disposal when targeting resources for conservation. For example, they can target resources that provide the highest

Figure 1: Major USDA Conservation Program Expenditures, Fiscal 1996-2022



Note: Working land programs include the Environmental Quality Incentive Program (EQIP), the Conservation Stewardship Program (CSP), program-related technical assistance, and predecessor programs. Values adjusted to 2021 dollars using the Gross Domestic Product Implicit Price Deflator.

Source: USDA (2023c)

environmental benefit per resource unit. The U.S. Fishery and Wildlife Service targets wetlands and other conservation resources based on biophysical criteria. Policymakers can also target marginal lands or least expensive resources for conservation. Previous studies have found that the enrollment patterns of the Conservation Reservation Program (CRP) were consistent with this targeting criteria at the early stage of its implementation. Policy makers can also target resources that offer the highest benefit-cost ratios or preserve resources that lead to the largest environmental benefit for a given budget, which is the stated objective of several recent conservation programs, including the EQIP and CREP. These four approaches have been referred to as benefit targeting, cost targeting, benefit-cost ratio targeting, and benefit-maximization targeting, respectively (Wu, Zilberman, and Babcock, 2001). Conservation-targeting approaches have evolved significantly over the years due, to a large extent, to our better understanding of the economic, environmental, and distributional implications of these targeting approaches.

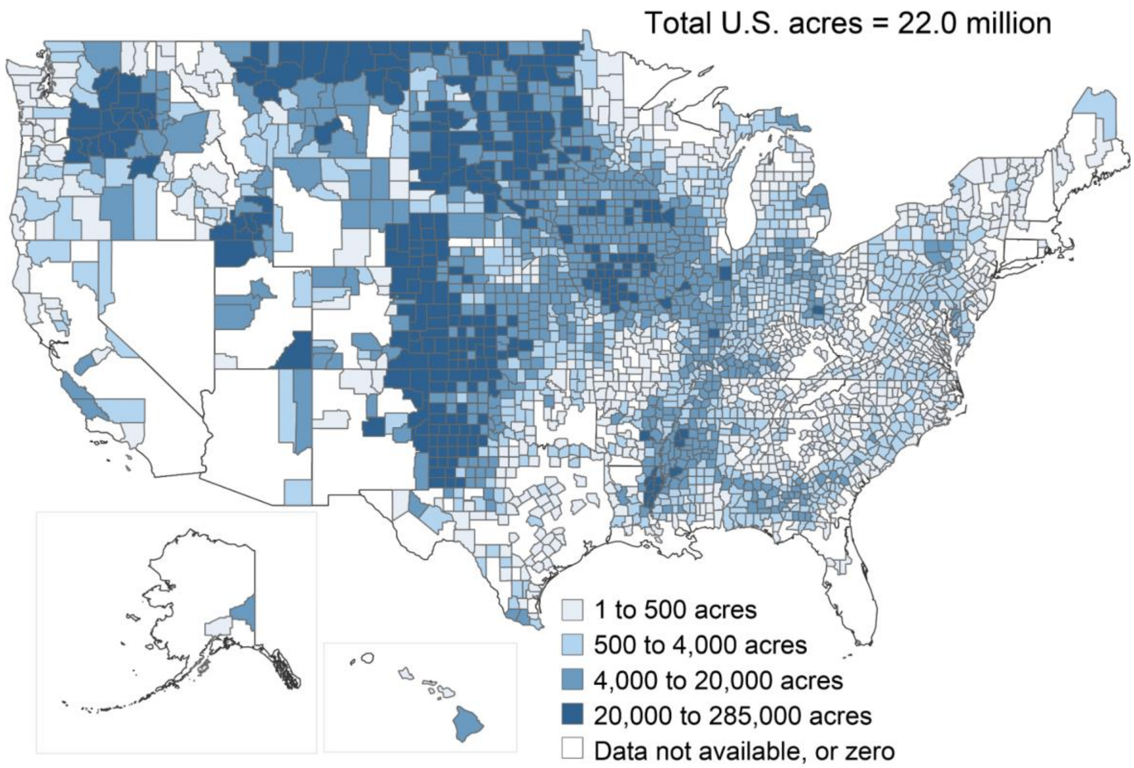
Performance of Alternative Targeting Criteria

Different targeting criteria can lead to dramatically different economic, environmental, and distributional outcomes. Wu, Zilberman and Babcock (2001) compared the performance of alternative targeting criteria in terms of 1) the amount of land in conservation, 2) the amount of land in production, 3) total output, 4) output prices, 5) total environmental benefits, 6) consumer surplus, and 7) producer surplus. They found that cost targeting leads to the largest amount of land in conservation and the smallest amount of land in production. As a result, it leads to the lowest total output, the highest output price, and the largest producer surplus. Thus, cost targeting should be the landowner's most favored targeting strategy. In addition, cost targeting leads to the lowest demand for labor and other agricultural input. Thus, it should be labor and input suppliers' least preferred strategy. Cost targeting is the most pro-poor policy if the poor are the landowners. However, if the poor are laborers or input suppliers but not the landowners, it will be the least pro-poor policy. Zilberman, Lipper, and McCarthy (2008) argued that PES is not necessarily progressive; it may actually hurt the poor.

In contrast, benefit targeting leads to the lowest output price and the highest consumer surplus because it leads to the smallest amount of land in conservation and largest amount of land in production. Therefore, it should be consumers' most preferred strategy, particularly among those who benefit little from the environmental improvements. Labor and input suppliers may also support this strategy because it leads to the largest amount of resource in production and the highest demand for labor and other agricultural input. It is the landowners' least preferred strategy because it results in the lowest output price and the smallest producer surplus.

Benefit-cost ratio targeting is the most efficient strategy (i.e., maximize the sum of producer surplus, consumer

Figure 2: Conservation Reserve Program Total Enrolled Acres by County, 2022



Note: Total acres include continuing and newly enrolled acres as of September 30, 2022.

Source: USDA (2023b)

surplus, and environmental benefit for a given budget). However, it is not the most preferred strategy of any interest group.

Benefit-maximization targeting would be equivalent to benefit-cost ratio targeting if the output price were not affected. However, if the conservation program is large enough to raise the output price, benefit-maximization targeting will generate more environmental benefits for a given budget than benefit-cost ratio targeting. By preserving more high-benefit and high-cost resources, benefit-maximization targeting will cause less reduction in total output and a smaller increase in output prices. As a result, fewer acres of marginal land will be brought into production (i.e., less slippage).

Another important political economy consideration in the design of agri-environmental programs is the spatial distribution of program benefits among jurisdictions. For example, CRP land and the associated economic and environmental benefits are highly spatially concentrated, with most program benefits being accrued to the Great Plains, Montana, the Columbia River Basin, and some areas in the Corn Belt (Figure 2). Given that broad program participation has been an important policy goal, it is important to ask if it is possible to spread the program's benefits without sacrificing its efficiency.

Wu and Yu (2017) analyzed this issue using individual bid data from the 18th CRP sign-up. They showed that if a farmer is compensated for their opportunity cost of participation, maximizing environmental benefit per dollar expended is equivalent to maximizing the Marshallian aggregate surplus (i.e., the sum of consumer surplus, producer surplus, and total environmental benefits). Therefore, they measured efficiency by the total environmental benefit per dollar expended. In addition, they measured distributional equity using several indicators, including a Gini coefficient constructed based on the CRP payment per capita of rural farm population. They also measured the performance of different targeting criteria relative to the efficiency-equity frontier. They found that the USDA forfeited about 9% of efficiency for an 18%–23% gain in distributional equity, depending on the equity indicator used. The CRP targeting criterion could be redesigned to achieve both higher efficiency and higher distributional equity.

Challenges for Designing an Efficient Conservation Program

Historically, U.S. conservation programs have been designed to protect specific resources, managed by different agencies, and targeted using some onsite, physical criteria (Wu and Boggess, 1999). A major problem with such a targeting approach is that it ignores some key features of ecosystems, including threshold effects, ecosystem linkages, and spatial interactions among ecosystems.

A threshold effect is present when a significant environmental improvement can be achieved only after conservation efforts reach a certain threshold (Wu, Adams, and Boggess, 2000). Threshold effects have been found in many conservation efforts, particularly those involving fish and wildlife. For example, in a study of the relationship between the northern spotted owl survival and suitable habitat, Lamberson et al. (1992) found that when suitable habitat is less than 10% of the landscape, the chance for northern spotted owl survival is almost zero, however, when suitable habitat reaches 15% of the landscape, the chance for survival reaches 80%, and when suitable habitat reaches 20% of the landscape, the chance for survival reaches 95%. This nonlinear relationship has important implications for conservation fund allocation: If conservation funds are divided equally between two watersheds and the funds are only enough to restore 10% of landscape in each watershed, little benefit would come out of the effort in terms of northern spotted owl survival. However, if all money is allocated to one watershed and 20% of the landscape is protected, the chance for survival in this watershed would reach 95%. This simple example suggests that when threshold effects are ignored, funds tend to be overly dispersed geographically, and substantial benefits could be lost.

We have conducted several case studies to demonstrate the importance of considering the threshold effect in the design of conservation programs. In every case study, we found that program efficiency would increase significantly if this key feature of ecosystems were considered. For example, in one of the case studies, we focus on salmon restoration in the U.S. Pacific Northwest. Salmon restoration is an important issue in the region because salmon have disappeared from 40% of their historical breeding ranges, and many of the salmon runs have been listed as endangered and threatened under the Endangered Species Act. Because of the complex life cycle of salmon, many reasons have been cited for the declining salmon population, including overharvesting, unfavorable ocean conditions, dams that block their migration routes, and freshwater habitat degradation caused by land use practices such as deforestation and grazing. To address the problem of declining fish population, billions of dollars of taxpayer money have been spent on salmon restoration during the last 30 years. A common practice in habitat restoration is to target streams for restoration based on riparian conditions. For example, under Oregon and Washington’s Conservation Reserve Enhancement Programs, farmers are compensated for restoring riparian conditions along the salmon streams.

Threshold effects are present because of the nonlinear relationship between stream water temperatures and fish production. Salmon, a cold-water species, cannot survive when the temperature is above a certain level. However, when targeting is based on riparian conditions, streams with very high temperatures may receive funding, even if conservation efforts will not lower temperatures enough to benefit fish. Similarly, streams that have very low temperatures but poor riparian vegetation, may be targeted for conservation. Improving streamside vegetation in those streams will not generate any benefit. Wu and Skelton (2002) calculated benefit losses if targeting is based on stream riparian conditions and found that such on-site targeting criteria could lead to substantial benefit loss.

The second problem with the traditional targeting approaches is that they ignore the relationships between alternative environmental benefits. Such relationships can take two forms: interactions or correlations (Wu and Boggess 1999). Interactions refer to the causal relationships between different environmental benefits. For example, improving stream water quality also enhances fish habitats. The correlation refers to the situation where the same conservation effort jointly produces two environmental benefits, although these two benefits have no causal relationship. For example, land retirements provide both wildlife habitat and groundwater quality benefits, although the two benefits have no direct causal relationship.

To demonstrate the importance of considering ecosystem linkages, Wu and Skelton (2002) examined the effect of stream water temperatures on a warm-water fish species (speckled dace) and a cold-water fish species (rainbow trout) in several watersheds in Oregon. As riparian conditions improve and the water temperature goes down, the number of speckled dace decreases while the number of rainbow trout increases. Four speckled dace would be lost for every $100 gained from increasing cold-water fish species. Speckled dace is not an endangered species, so the trade-off favors the cold-water species. But if the warm-water species were also an endangered species, the decision would not be as clear cut.

The third problem with the current targeting approaches is that they ignore the spatial interactions between ecosystems. Spatial interactions of ecosystems can take many forms, some more subtle than others. For example, land use upstream affects water quality downstream. Conservation in one place may affect environmental quality in the surrounding areas.

In a case study of the Grande Ronde Basin in Oregon, Watanabe, Adams, and Wu (2006) demonstrated the importance of considering the spatial interactions in the design of conservation programs in a river system. If the objective is to reduce water temperatures at the end of the basin downstream and the desired temperature reduction is only 1ºC, the most efficient way to achieve this objective is to restore riparian conditions near the end of the basin. However, as the desired temperature reduction increases, it becomes necessary to apply conservation in upper stream reaches. If the desired temperature reduction is 4ºC or above, the riparian buffers for the entire basin need to be restored. Also, the optimal spatial allocation of conservation efforts can be dramatically different for different water quality standards. Furthermore, if the ultimate objective is to maximize salmon populations in the basin, targeting based on water quality can be very inefficient. For example, if the water quality standard is 22º C and the fund is allocated to maximize the stream length where the water quality standard is reached, it can only achieve 12% of the total benefit that would be obtained when the conservation efforts are targeted explicitly for fish benefits.

Approaches to Improving Conservation Efficiency

In the presence of threshold effects, ecosystem linkages and spatial connections, a three-step approach can be used to improve program efficiency. First, divide the entire landscape into small basins. This requires a thorough consideration of soils, climate, vegetation, and the region's topographical, hydrological, and biological features. Each basin must be large enough to include a whole watershed and small enough to capture the spatial variations across the landscape. For example, New Zealand is divided into 85 ecological regions and 268 ecological districts using information about geology, topography, climate, and biota to establish a bio-reserve system (New Zealand Biological Resources Centre, 1987). U.S. Environmental Protection Agency (2023) uses a watershed approach to address water resource challenges, and claims it is the most effective framework.

Once the basins are defined, in the second step, a bidding process like the one used in the CRP could be used to select resources for conservation. Each bid must specify the conservation practices it will adopt and the annual rental payment from the program.

In the third step, bids are accepted into the program based on benefit-cost ratios. In addition, fund allocations across basins should ensure that 1) thresholds are reached in all funded basins and 2) the marginal benefits of conservation spending are equalized across the funded basins. In some situation, threshold effects may be unobservable. If so, policymakers could adopt an all-or-nothing approach: conserving all or nothing in a basin. This all-or-nothing approach could be more efficient than an approach that pay for the targeted benefit explicitly in the presence of threshold effects (Lewis, Plantinga, and Wu, 2009).

Concluding Comments

In most conservation investments, strong non-linearities and ecosystem linkages can mitigate politically feasible targeting criteria. The design of agri-environmental programs must consider these complexities. Formulas or guidelines based on political consideration, or keyed to a specific on-site physical criterion, can result in substantial efficiency losses. In addition, the design of agri-environmental programs must consider their distributional implications; while a well-designed agri-environmental program can be progressive, a poorly designed one can be counterproductive. Previous studies suggest programs that enhance agricultural practices tend to lead to more employment, whereas land diversion can have the opposite effect (Zilberman, Lipper and McCarthy, 2008). With growing concerns about climate change, PES can play a key role in introducing conservation practices that increase carbon sequestration and build resilience to climate change (Rausser and Zilberman 2023). While challenges are daunting, they are not insurmountable. With the aid of artificial intelligence, machine learning and other advanced technologies, interdisciplinary collaboration in the design of conservation programs can lead to large improvements in both efficiency and distributional equity.

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CHOICES

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Agricultural Soils and the Quest for Net Zero Emissions

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Introduction

Climate change impacts how we live, work, and grow food/fiber. It affects agriculture directly by altering productivity and indirectly through efforts on adaptation (which reduces damages without changing the extent of climate change) and mitigation (which reduces drivers of climate change like greenhouse gas emissions and thus alters the future extent of climate change). This paper will cover mitigation, primarily considering prospects for storing (sequestering) carbon in agricultural soils. In treating this possibility, we will cover 1) reasons why this topic is of current interest, 2) the physical characteristics of sequestering carbon, and 3) what influences the value of sequestered carbon, along with comments throughout on implications for policy design.

Why Consider Soil Carbon Sequestration

Every year, the earth goes through a cycle of vegetation growth, during which it absorbs carbon dioxide from the atmosphere, then later vegetative decomposition, releasing carbon back into the atmosphere. This results in a large carbon flux between the atmosphere and the Earth's ecosystem. Concurrently, substantial carbon infiltrates into the soil through roots and decomposing material. A broad estimate of carbon sequestered in soils places its mass at about three times the amount of carbon resident in the atmosphere (Kayler, Janowiak, and Swanston, 2017). Additionally, the amount of carbon sequestered in soil has fallen, with estimates indicating historically that soils have been a source of 10%–20% of total anthropogenic contributions to the atmosphere (Sanderman, Hengl, and Fiske, 2017). In the face of this, the basic idea of soil carbon sequestration (SCS) mitigation is that we can modify the annual ecosystem/atmosphere exchange so that more carbon is retained using the current, underused soil storage potential.

Society may wish to increase SCS for a number of reasons. McCarl, Murray, and Antle (2002) list seven reasons for its pursuit. In this article, we update and augment the reasons to be reflective of today's context.

1) Greenhouse Gas Forcing and Climate Change. Climate change is increasingly being discussed as a disruptive force, with many indicating it is changing the environment in which we live and affecting actions and agricultural productivity (Intergovernmental Panel on Climate Change, 2014; Intergovernmental Panel on Climate Change et al., 2022; U.S. Global Change Research Program, 2018). Greenhouse gas (GHG) control is a means of addressing climate change. The concept of the United States hitting net zero emissions by 2050 has appeared in government documents, including from the White House (2021). There are also provisions for funding agricultural net emissions reductions like SCS in the Inflation Reduction Act of 2022 (117th Congress, 2022)

2) Compliance with International Agreements. The U.S. government is a party to the Paris Agreement, and the associated Nationally Determined Contribution document (United States of America, 2021) states an economy-wide target of reducing net GHG emissions by 50%–52% below 2005 levels in 2030. Strategies are also proposed in the document, including ones related to agriculture and SCS. More specifically,

> "Agriculture and lands: America's vast lands provide opportunities to both reduce emissions, and sequester more carbon dioxide. The United States will support scaling of climate smart agricultural practices (including, for example, cover crops), reforestation, rotational grazing, and nutrient management practices" (The United States of America Nationally Determined Contribution).

3) International Attitudes toward U.S. Emission Levels. Globally, the United States has the second highest level of total GHG emissions and is among the highest on a per capita basis (Ritchie, Roser, and Rosado, 2020). Internationally, the United States is viewed as having excess emissions, and movements toward lower net emissions would help alleviate that perception.

4) Domestic Pollution Related Policy. The Clean Air Act is a key part of U.S. air pollution policy. An EPA endangerment finding placed GHG control underneath that act (U.S. Environmental Protection Agency, 2021), although not much control activity has happened. Duffy et al. (2019) review the situation and argue that the basis for action is growing. Also, the Inflation Reduction Act of 2022 strengthens the case, amending the Clean Air Act to include GHGs as air pollutants, including carbon dioxide, hydrofluorocarbons, methane, nitrous oxide, perfluorocarbons, and sulfur hexafluoride (117th Congress, 2022).

5) Industry Planning in the Face of Uncertainty. Policy statements about the United States moving toward net zero emissions raise future cost risk for industries in which production is highly correlated with GHG emissions. This has led some industries, like electrical power generators, to explore ways of reducing emissions. SCS has been one strategy that has been investigated.

6) Need for Cheap Emission Offsets. Concerns have been expressed about how expensive it would be to reduce emissions, and there is undoubtedly a need for inexpensive options. Studies advocate agricultural actions, including SCS, as low-cost ways of reducing emissions (Murray et al., 2005).

7) Linkage to Other Goals for Agriculture and Environmental Impacts. SCS has implications not only for net GHG emissions but also for erosion rates, water quality, soil organic matter, yields, and farm income. Several U.S. programs have supported farm conservation activities with the goals of improving both the environment and income. Under the Inflation Reduction Act, the U.S. Department of Agriculture Natural Resources Conservation Service (2023) indicates that an additional $19.5 billion will support conservation programs that yield climate-change mitigation benefits, providing more producers with conservation assistance.

8) Development of Another Market for Farm Products. Agricultural markets are often such that increases in production lead to substantial decreases in price, mainly due to inelastic demand. Maintaining farm income has long been a concern of farm policy and has often involved supply control to raise prices. The potential volume of emissions in a comprehensive carbon market would be quite large, with the potential agricultural market share being small. Thus, SCS amounts would face much more elastic demand with little influence on the carbon price. In that case, increases in farm carbon production would lead to higher farm incomes, as when agricultural-based ethanol production entered the liquid fuels market.

Physical Characteristics of SCS

The amount of SCS in a location is influenced by numerous forces, including climate, vegetation, topography, soil type, management history, and disturbance. These forces create local, regional, and temporal heterogeneity in SCS. SCS can be enhanced through many practices, such as the use of cover crops, less intensive tillage, land use changes, afforestation, soil amendments, use of perennials, and incidence of deep-rooted crops, among other options (Paustian et al., 2016). These practices affect SCS by modifying the relative rates of carbon addition versus destruction in the soil (Paustian, Collins, and Paul, 1997).

SCS can not only be increased but also be depleted. In particular, if practices are altered, such that the carbon is exposed to oxygen by increased soil disturbance, or if the soil conditions are changed (becoming more arid, erosion increases, or increasing soil microbial activity because of increased temperature), then the amount of soil carbon will be reduced. In fact, this can occur quite rapidly (Olson, 2013). Practices, once begun, need to be continued to maintain the carbon SCS volume.

Additionally, it is important to note that soil carbon accumulation does not continue forever. Instead, as soil carbon is added to a particular amount of soil, this also increases soil carbon destruction, mainly through microbial activity. Under many practices, the soil carbon stock reaches an equilibrium generally in 10–15 years for practices such as less intensive tillage use (West and Post, 2002). Thus, the amounts sequestered decrease over time as equilibrium is approached (West and Six, 2007; West and Post, 2002)

Finally, it is worth mentioning that the effect of different management practices on SCS amount depends on soil conditions and climate, with a consequent regional variation in practice effects. Hutchinson, Campbell, and Desjardins (2007) provide evidence on the heterogeneity of the impact of SCS, as does the review in Ogle et al. (2023).

Issues Regarding the Value of SCS Enhancements

Many issues have been raised regarding the desirability of adopting particular practices to reduce net GHG emissions. Across the spectrum, several of these have led to the exclusion of strategies like SCS enhancement from implemented policies. Here we discuss issues that have been raised repeatedly.

Permanence

For many years, there have been concerns over the permanence of the carbon sequestered by SCS practices relative to other mitigation alternatives. For example, capturing and burning methane is a permanent removal from the atmosphere as the methane is eliminated and cannot come back. But sequestering carbon in soils and vegetation places it in potentially temporary storage, as the carbon may be released by reversals of practices such as intensifying tillage. Coupled with the fact that practices can be reversed, SCS may not be permanent. Several studies have argued that SCS should not be used as part of the strategy for addressing GHGs or that its price be discounted (as reviewed in Murray, Sohngen and Ross, 2007; and Kim, McCarl and Murray, 2008; Thamo and Pannell, 2016).

Additionally, soil carbon generally reaches a new equilibrium after a relatively short period (10–15 years for tillage and longer for land use change) in reaction to changing disturbance regimes (West and Six, 2007). Thus, policy needs to consider what to do for payments as the net carbon sequestration amounts diminish. In such a case, if payments are discontinued, producers could be incentivized to discontinue practices, possibly releasing the carbon previously sequestered. The latter issue led to suggestions for long-term contracts such as 100 years and for paying maintenance costs to maintain SCS stocks even after increases have halted (Kim et al., 2008; Thamo and Pannell, 2016). These impermanence features diminish the value of the soil carbon due to its potential future release and/or need for maintenance payments. Longer-term commitments also reduce the desirability of farmer participation (as they limit future options) and raise transaction costs (as there would be a need to monitor whether the practice were continued on a piece of property for several generations).

In policy design, consideration needs to be given to: 1) the length of the contract, 2) the consequences for anyone who reverses practices, and 3) the encouragement of practices that store carbon in more permanent forms, such as deeper in the soil and/or in forms that resist degradation, like biochar. Additionally, it may be desirable to target practices that reduce soil disturbance, such as moving croplands into grass or afforestation. Finally, policy design could formally recognize the impermanency of SCS using discounted prices or limited duration carbon leasing (Kim et al., 2008). For example, a lease might mandate sequestration for 20 years, giving time to develop emission reductions from other sources, as discussed in McCarl and Sands (2007).

Uncertainty

The uncertainty of SCS amounts under alternative practices is important for several reasons. First, the regional heterogeneity of SCS amounts and responses to practices imposes a burden: Region-specific information on the amount of carbon sequestered must be developed. Second, the spatial pervasiveness of carbon in the soil means that it can never be measured, only estimated, and is thus subject to error. Third, Kim and McCarl (2009) find that in models, variability in soil carbon increments are highly correlated (over 90%) with variability in crop yields, which we know to be highly variable over time and space. This means that carbon uptake rates will also be highly variable over time and space. Kim and McCarl (2009) propose addressing uncertainty in policy design by forming spatially diverse, multiyear portfolios to reduce variability.

Additionality

One concern that has been raised for years is the desire for additionality when funding mitigation actions. Namely, there is a desire arising from the efficiency of spending funds that people be paid for a practice that improves carbon sequestration only if they would not have used that practice in the absence of payment. This raises issues regarding “good actors,” those that have already been using a practice before a policy is implemented. For example, under strict additionality in the case of no-till, only new individuals who previously had not been using no-till would be eligible for payments. However, there is debate over whether we should reward farmers already using the practices for the SCS they have accumulated. Obviously, paying for existing practices increases the program cost, but it would reduce the likelihood that some farmers might reverse practices to become eligible for the payment, thus losing SCS. Several treatments have addressed the issue (Weinberg and Claassen, 2006; Murray, Sohngen, and Ross, 2007; Smith et al., 2007). Policy approaches could include 1) targeting only those with a new practice change for full payment, 2) paying a maintenance cost or a graduated fee for existing practices depending on when the practice has begun, or 3) paying the full fee for existing practices motivated by protecting the stock or reducing transactions cost.

Leakage

One phenomenon that can arise in association with climate-smart agricultural practices involves emissions leakage. Leakage occurs when actions in one region reduce the amount of product moving into the marketplace, causing higher prices and leading to production and GHG emission increases elsewhere. Some climate-smart agricultural practices can reduce production and thus stimulate such leakage. For example, evidence shows that the use of cover crops slightly reduces the yield of conventional crops (Deines et al., 2023). In turn, following the line of leakage arguments presented in Murray, McCarl, and Lee (2004), increases in the use of cover crops that reduce production would lead to an increase in crop prices, which in turn would stimulate additional production, emissions, and land use changes elsewhere (as discussed in the indirect land use dialogue related to biofuels; see Searchinger et al., 2008; Hertel and Tyner, 2013).

Addressing emission leakage in the policy context is difficult. But the policy could possibly be designed not to incentivize anything that reduces conventional production or include some form of discount when leakage occurs. Examples of leakage estimation and a price discounting approach can be found in Murray, McCarl, and Lee (2004); Gan and McCarl (2007); and Kim, Peralta, and McCarl (2014).

Accounting for the Full Spectrum of Greenhouse Gases

Only focusing on CO_2 reduction by SCS can stimulate additional emissions of other GHGs, which offsets the SCS CO_2 reduction effects. Namely, some SCS-enhancing possibilities involve the usage of emission causing inputs, and these may positively and/or negatively impact the net GHG emission effect of the SCS activities. For example, using cover crops may require the use of additional nitrogen fertilizer to maintain crop yields or may involve directly using nitrogen-fixing legumes as cover crops. Such outcomes can increase emissions of nitrous oxide, a gas that has about 300 times the effect on retained heat as does carbon dioxide. Again, policy approaches could prohibit anything that adds emissions in other categories and/or require a complete lifecycle GHG accounting across the practice. For example, see the discussion in Schlesinger (2000) relative to nitrogen fertilization, the lifecycle example in McCarl et al. (2009) regarding biochar, and the analysis in Gleason et al. (2009) on trade-offs between SCS and increased methane emissions.

Transactions Costs

Last, another policy design consideration that merits discussion is transaction costs. Programs that distribute money for SCS payments require intermediaries for program administration; consequently, programs will cost more than the sum of payments made to farmers. When farmers pay for crop insurance, for example, about 30% of their payments are retained by the local agent and 70% goes to the overall insurance company. A similar proportion of transaction cost is expected in the case of SCS. Alston and Hurd (1990) estimate that the transaction costs of administering the farm program ranged from $0.25 to $0.50 for each $1.00 distributed. McCann and Easter (2000) find transaction costs to be 38% of total expenses or over 50% of direct payments. Further, if one uses an average carbon sequestration rate of somewhere around 1 metric ton per acre, then producing 1 million tons of SCS would require the involvement of around 2,250 average-sized (445 acres) U.S. farms and a lot more for smaller operations such as exist in developing countries. This implies that the cost of administering the program may be as much as 50% above the amount of money that finds its way to producers and has implications for the cost of achieving SCS offsets. Thus, in establishing policy, substantial attention needs to be paid to controlling transaction costs so they do not become excessive.

Concluding Comments

As the United States strives to reduce its net GHG contributions to climate change, agricultural soil carbon sequestration is one strategy identified as a way of making progress. In encouraging soil carbon sequestration, there are some critical considerations involved with policy design, including 1) how much sequestered carbon will be stored, 2) how long it will last, 3) uncertainty regarding the amount of carbon sequestered; 4) how much it will cost; 5) how to maintain existing stocks; 6) effects of practices on the full suite ofGHGs; and 7) the potential added cost of administering the program. In this article, we outlined some of these issues and possible policy ways to address them, but clearly more work and careful policy design choices are needed.

For More Information

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