Economic Doctrines and Approaches to Climate Change Policy

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Recognizing that approaches to mitigating climate change emanate from well-defined schools of economic thought should help policymakers better understand the fundamental choices involved in addressing the reduction of greenhouse gas.

Climate change is one of the defining issues of our time, and it presents fundamental choices between current behaviors and stewardship of future resources. Yet, in spite of the importance of getting the policy response right, there is intense debate over different solutions, even among those who acknowledge that climate change is real and is human made. Until recently, the prevailing policy proposal was cap and trade, but other solutions have also been proposed, including: carbon taxes; direct emission regulations; subsidies or regulatory requirements for existing renewable energy; and support for clean energy innovation. The lack of consensus on the right approach to climate change stems from a variety of issues including debate over causal factors of climate change and the contention of affected interests; however, a lack of consensus on the underlying approaches (or doctrines) that should guide economic policy broadly plays a key role in the debate.

Ultimately, climate change is an environmental phenomenon with serious economic implications; thus, proposed polices seek to reshape economic activity. Yet, the solutions to climate change and its economic impact are so varied and complex that it is difficult to come up with the "empirically correct" solution. As a result, advocates and policymakers rely on economic "world views" or doctrines to guide their policy deliberations, and the resulting policy approaches are a function of these competing doctrines. Favored climate change policies reflect the principles of economic doctrines that suggest how economies work and, with respect to climate change, how environmental problems arise and possible solutions. Recognizing that approaches to mitigating global climate change emanate from well-defined schools of economic thought that have emerged through the lens of political discourse should help policymakers better understand the fundamental choices involved in addressing the reduction of greenhouse gas (GHG) emissions and hopefully lead to the development of more effective policy responses.

This report explains in detail how four competing economic doctrines interact with and support political ideologies present in the climate change policy debate and proposed solutions. Different actors in the policy debate (advocates, government officials, the media, and legislators) all subscribe, knowingly or not, to an economic doctrine. Currently, in the United States, they most likely hold one of the following three doctrines: conservative neoclassical, liberal neoclassical, and neo-Keynesian economics, which are all grounded more in the 20th century than the 21st. However, supporters of an emerging economic doctrine "innovation economics," – an approach grounded in the growth economists that first came to political attention in the 1980's – not only offer a critique of the others' fundamental views of the economy and climate change, but also articulate an alternative approach to climate change policy. The four doctrines form the current political and economic landscape of climate change proposals.

Each of the four doctrines competes for the attention and allegiance of U.S. policymakers. The issue of how best to address climate change provides a perfect example of how the prevailing doctrines are driving less-than-optimal policy solutions and discourse. Even though the doctrines are not precise analogues of climate change positions, they do serve as broad frames of reference for climate policy proposals.

Holders of the neoclassical economics doctrine see climate change as a relatively straightforward problem attributable to a simple error of not charging emitters of greenhouse gases (GHG) for the full costs of their emissions. However, policymakers informed by conservative neoclassical economists, such as Greg Mankiw, a former chair of the Council of Economic Advisors under former President George W. Bush, are more likely to favor a simple carbon tax, while liberal neoclassicalists favor cap and trade as a way to set a price on carbon as Lawrence Summers, Director of the National Economic Council and Assistant to President Obama for Economic Policy, has suggested. Both believe that once the price is right, the market will respond appropriately and develop the needed technologies. In contrast, those informed by neo-Keynesian perspectives favor a more direct response such as setting a limit on GHG emissions through emission caps and renewable energy portfolio standards, and subsidizing current generators of renewable energy. Environmentalists like James G. Speth, an environmental lawyer and founder of the World Resources Institute, seem to prefer this approach. Finally, holders of the innovation economics doctrine argue that price signals alone are insufficient to drive clean energy transformation and that carbon taxes that explicitly support clean energy innovation policies to spur research, development, and deployment of next generation alternatives are the preferable solution.

This report provides an overview of these economic doctrines, and then describes how current climate change proposals reflect the principles and goals of each doctrine. It offers a critique of the advantages and limitations of each doctrine's approach to addressing the challenge of climate change. It concludes by arguing that an approach to climate change policy grounded in innovation economics and in prioritizing clean energy innovation promises the most effective path to solving global climate change.

Economic Doctrines in Policy Competition

The role of economic doctrines in the public policy process is pervasive, involving far more than economists generating economic reports and forecasts. The derivations of economic doctrines are steeped in philosophies concerning the essential factors of a stable and growing economy and what types of policy interventions, if any, are appropriate to promote economic growth. Economic world views as adopted in the political marketplace are like political ideologies; and everyone, not just economists in government agencies, Congressional committees, and think tanks, possesses basic beliefs that economic doctrines instruct. The doctrines guide their thinking and deliberations and help them make sense of a complex and rapidly changing economy. This article is focused on the economic thinking that has come to the forefront in the political debate around climate change policy, not on economics as economists would necessarily describe it.

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Today, Washington policymakers rely on, and implicitly or even sometimes explicitly embrace, three prevailing, 20th century economic doctrines: (1) conservative neoclassical (sometimes called "supply-side"); (2) liberal neoclassical (sometimes called "Rubinomics," referring to the policies of President Bill Clinton's Secretary of the Treasury Robert Rubin); and (3) neo-Keynesian, a modified Keynesian response to neoclassical economics. Economic doctrines don't emerge and become adopted on the basis of scholarly arguments alone. Rather, the reverse is often the case—the political direction emerges, and inspires a range of available and justifying economic ideas. The economic and social structures of an era also profoundly shape what economic doctrines emerge into political discourse and which policies are effective. The reaction against pure Keynesian economics, as a result of 1970s stagflation, was especially notable among conservatives. In response, they crafted a neoclassical alternative to Keynesian economics known as "supply-side economics," which remains the dominant economic paradigm for many conservatives to this day.[1] More politically moderate neoclassical economists embrace many of the same principles as supply-siders but have developed a neoclassical economic doctrine that incorporates their own belief in a stronger role of government and greater economic equity. Meanwhile, a group of neo-Keynesian economists on the left offer ideas that they hope are better able to explain current economic events than the original Keynesian doctrine developed after the Great Depression.

In the last two decades, however, a small but growing share of economists have argued that the dominant doctrines were failing to address critical and complex economic dynamics, especially with respect to technological change and innovation. Recognizing fundamental limitations in prevailing doctrines, a number of economists proposed a new economic doctrine, referred to here as innovation economics. Among other things, it seeks to explain the anomalies that the prevailing doctrines prefer to ignore.[2]

The influence that economics has on policy development in the United States is rooted in the discipline's evolution from the political economy insights of Adam Smith into formal mathematical models that are currently the primary manner in which economic knowledge is conveyed, particularly for neoclassical economics. Simplifying all economic interactions into mathematical models fails to capture much of the real world in terms of complexity, uncertainty, and risk that accompanies most interactions. As computers have enabled greater mathematical rigor, economic models have attempted to capture more behavioral and complex issues—climate change, for example. However, even these successes do not allow those with little economics training to fully appreciate how basic assumptions affect outcomes. Consequently, economists are set apart, revered and feared in most policy discussions because of the prevailing belief that if the numbers say it, it must be so.

Neoclassical Economics

Nowhere is economics' influence on public policy more prevalent than in neoclassical economics. As introduced above, two strains of neoclassical thought exist, based mainly on political ideology, with conservative and liberal camps. Both embrace several basic principles that guide, and we believe, restrict policymakers from fully addressing climate change. In particular, neoclassical economists believe that setting a price on carbon—through a carbon tax or cap and trade—is the principal and often sole policy response needed to address climate change. Below we briefly explain the basic principles before turning to how these are absorbed into conservative and liberal neoclassical approaches to climate change.[3]

One of the primary principles of neoclassical economics relevant to the issue of climate change is that **economic growth is achieved by maximizing allocative efficiency**. Society receives the greatest net benefit when the distribution of available resources results in a desired quantity of goods. This occurs not only because the most efficient allocation of resources results in the maximized net benefit through their use, but also because the prices consumers are willing to pay for the produced goods equal the marginal costs of production. That is, supply equals demand across all markets in the economy. From the standpoint of a neoclassical economist, it would be a violation of this principle to propose a policy that would alter the "natural" allocation of factors like capital, labor, and goods and services. Regulations, taxes, market power, or other "distortions" will not maximize allocative efficiency because the resulting market-price signals do not reflect the free choices of individuals and firms. The subsequent loss of allocative efficiency is, in their words, a "deadweight loss" that decreases both producer and consumer surplus in market transactions. On this principle, both supply-siders and liberal neoclassicalists agree: any government intervention or policy that distorts allocative efficiency will harm economic growth.

The neoclassical focus on market transactions that maximize allocative efficiency is based on several other principles. One is that the economy is built upon the interaction of firms and consumers in **markets determined by price signals.** Indeed, allocative efficiency revolves around the responsiveness of economic agents to price signals. Consequently, neoclassical economists emphasize "price mechanisms" like interest rates, currency values, inflation, and other monetary factors that determine the value of capital and labor more than institutional factors such as the rate by which firms are developing and adopting new technologies. The dominant focus on price signals also explains why formal mathematical models have become the language of neoclassical economics, while less quantifiable factors such as economic history, culture, norms, and institutions are in the periphery.

The belief that supply normally meets demand is another neoclassical principle. In this paradigm, the economy is simply a large market of goods and services that is **generally in equilibrium** and usually best left to itself. Equilibrium occurs when a market price is established through competition such that the amount of goods or services sought by buyers is equal to the amount of goods or services produced by sellers. Because the economy tends toward equilibrium in the neoclassical view, the main task of economic policy is simply to reduce artificial barriers and impediments to market equilibrium, particularly by ensuring that prices are aligned with marginal costs.

A final relevant principle of neoclassical economics is that **individuals act in response to incentives to rationally maximize their own self-interest**, and that the collective pursuit of individual self-interest will also maximize public interest. According to Adam Smith, the individual who "intends only his own gain" will, in the course of maximizing his needs, be "led by an invisible hand to promote…the public interest." Although this generally may be true, new research in behavioral economics is showing that it is not always the case.

In the last two decades a small but growing share of economists have argued that the dominant doctrines were failing to address critical and complex economic dynamics, especially with respect to technological change and innovation.

Although conservative and liberal neoclassicalists agree on many key economic principles, they differ in some important ways. In general, conservative neoclassicalists view markets as less prone to failures, a compelling case for limited government intervention. Liberal neoclassicalists, however, consider market failures to be more common, but still generally limited. They are more willing to advise government intervention in the economy in the cases of the following market failures:

1. Public good provision, where the market doesn't produce enough of the desired good on its own, such as roads;
2. Externality, where market agents do not enjoy all of the benefits or incur all of the costs of their actions, as with the negative externality of GHG emissions, a by-product of a process whereby emitters do not bear the complete costs of emissions;
3. Information asymmetry, where inefficiencies arise because information about a good's attributes as distributed between a buyer and seller or the attributes of an externality between the generator of the externality and an affected party lead to issues like adverse selection and moral hazard; and
4. Economies of scale, where the unit costs of an activity continue to fall as the scale of the activity increases, which can result in barriers to potential new market entrants and allocative- or X-inefficiencies like cost, operating, productive, and technical inefficiencies.

Beyond these market failures, liberal neoclassicalists are more likely to be willing to support intervention in the pursuit of greater economic equity and fairness, a market consequence that conservative neoclassicalists generally do not seek to correct through government action. Consequently, liberal neoclassicalists are more likely to recognize the limitations of a free competitive market and will take steps to address distributional effects.

Neo-Keynesian Economics

The British economist John Maynard Keynes and his followers greatly influenced economic attitudes in the three decades after World War II. But during the economic stagflation of the mid-1970s, neoclassical conservatives and many moderates "overthrew" the Keynesian mantle, reacting to Keynesian doctrine that seemingly failed to address the economic crises of the time. Many liberals countered by adapting the principles of Keynesianism to incorporate the new global, dynamic, and technology-driven economy. This "neo-Keynesian" doctrine—generally held by individuals on the liberal side of the economic spectrum—maintains that **economic growth is a result of business investment, government spending, and consumer spending because of the demand for goods and services it produces**. This key principle shapes neo-Keynesian economic policies as they tend to focus on increasing government spending, with the belief that such investment will lead to increased aggregate consumer demand.

With their focus on demand-led economic growth, neo-Keynesians give little attention to the "supply-side" of the economy, or the factors that directly influence what producers do. In a neo-Keynesian's view, policies, such as costly regulations, that might negatively impact the supply-side have little effect on overall economic growth. For this reason, they are more willing to support direct government regulation of economic activity. According to neo-Keynesians, if companies think consumer demand is increasing, they will have an incentive to invest more; they contend that government can do little to directly spur more growth, other than ensure high levels of aggregate demand.

Neo-Keynesian doctrine also posits that economic policies are designed to maximize not efficiency, but social welfare, defined as a more **equitable distribution of wealth and the achievement of social policy objectives** (such as a clean environment, small business growth, etc.). Neo-Keynesians argue that outcomes in a market-based economy are more sustainable if there is an equitable distribution of wealth. Neo-Keynesians see most economic issues in terms of who receives the benefits: working people and small and/or "socially beneficial" business, like "green business," or wealthy individuals and corporations. Equitable distribution of income and wealth lead to greater consumption since low- and moderate-income individuals have a higher propensity to consume, which in turn will lead to greater economic growth. Neo-Keynesians, even more than liberal neoclassicalists, focus on ensuring that the fruits of economic growth are distributed fairly, instead of supporting policies that would enhance productivity or spur innovation directly. Moreover, because fairness and other social outcomes are so important to them, neo-Keynesians give little attention to issues of allocative efficiency, making them more willing to support regulations that "distort" economic activity.

Innovation Economics

Unfortunately, none of the three prevailing doctrines offer the kind of economic policy framework suitable to the new economic realities of the 21st century. This is largely due to three factors. First, each doctrine focuses in an almost Newtonian way on adjusting the demand or supply of capital and labor to keep the economy in equilibrium and to secure economic growth, which undervalues the importance of innovation. Second, each concentrates on macroeconomic factors, particularly prices, rather than on the institutional- and technological-change factors that drive growth, albeit in different ways in different countries and times.[4] Finally, none of the prevailing doctrines' principles focus on the complex process of technological innovation and the messy and complicated world of firms, industries, and national innovation systems as these institutions relate to economic growth. [5] While neo-Keynesians recognize that these institutions matter, neoclassicalists fail to do so, and neither creates strategies relevant to them.

The relegation of innovation to, at best, a secondary economic-growth factor is problematic given our recent history, where innovation has transformed the economy and powered growth. The lack of attention to innovative forces has resulted in the use of 20th century conceptualizations, models, and theories to address 21st century challenges. A number of economists have acknowledged this logical inconsistency. In response, they have developed a new theory and narrative of economic growth to explicitly address and model how innovation occurs.[6] The doctrine of "innovation economics" reformulates the traditional model of economic growth and recognizes knowledge, technology, entrepreneurship, and innovation as primary factors for economic growth rather than as independent forces that are largely irrelevant in the prevailing doctrinal approaches to economic growth.[7]

Neo-Keynesians prefer a command and control approach that sets rules on the market (regulations) and provides subsidies to ensure a level playing field among low- and high-carbon energy sources.

Beyond the central tenet that **innovation drives economic growth**, innovation economists suggest that **productive and adaptive efficiency are the key to understanding how innovation creates growth**. Productive efficiency is the ability of organizations to reorganize production in ways that lead to the greatest output with the fewest inputs, including labor inputs, while adaptive efficiency refers to the ability of economies and institutions to change over time in response to new situations, in part by developing and adopting technological innovations. Thus, innovation economics suggests that the goal of economic policy is to improve productive and adaptive efficiency, allowing an individual, an organization or firm, and even broader entities, such as industries, cities, and entire nations to be more productive and innovative.

This contrasts with a neoclassical economist's primary concern for allocative efficiency. As innovation economist Richard Lipsey states, "Neoclassical theory stresses the creation of an efficient, or optimal, allocation of resources and derives a unique set of policy prescriptions that apply with equal force to all economies and all activities, whatever their differences."[8] From the standpoint of an innovation economist, however, if government policies that encourage innovation also "distort" price signals and result in some minor "deadweight" loss to the economy, so be it, because the benefits of productive and adaptive efficiency normally far exceed any costs to allocative efficiency. In fact, in an innovation economist's world where productive and adaptive efficiency matters and market failures are the norm, the role for the public sector is more compelling—it should institute explicit and effective innovation economics policies. Thus, while the neoclassical impulse is to remove market imperfections or distortions, innovation economics embraces many of those same imperfections and characterizes them as important sources of endogenous technological change and growth in a dynamic economy. Consequently, some neoclassical "impediments" to growth are sources that innovation economics policies seek to encourage.

Such policy is particularly apt in areas of the economy, like energy, in which **complex institutional systems shape the process of innovation**, and where the notion of a "market" as a unifying principle is too limiting. Economists Richard Lipsey, Kenneth Carlaw, and Kenneth Beker argue that in certain sectors the pressure that firms continually face about choices of how much and what type of innovation to attempt is not dependent on price but on prior capabilities.[9] Thus, a firm's currently feasible innovation choices evolve endogenously in a path-dependent way. The United States' implicit and explicit policy support of fossil fuels has created immense path dependency in the energy sector; these complexities are not fully amenable to price-induced change. Furthermore, Paul C. Stern of the National Academies of Science notes that the neoclassical assumption that demand is a smooth function of price, discounts the speed at which price can greatly change behavior and fails to recognize that the responses to price increase and decrease are not symmetrical.[10] Firms tend to respond more to prospects of loss than to prospects of gain, institutionalizing path-dependent responses.

Accordingly, innovation economics endorses government support of innovation and rejects the neoclassical economic depiction of innovation as an exogenous process that is solely responsive to price signals or that falls like "manna from heaven."[11] Instead, the economy's productive and innovative power is enhanced only through actions of workers, companies, entrepreneurs, research institutions, and governments. Thus, while neoclassical economists study markets, innovation economists study how firms, research institutions, governments and other institutions can best spur innovation. To **induce innovation is to be proactive with economic policies to facilitate learning and innovation among economic actors and support the institutions**— including culture, organizations, laws, and networks— that spur innovation. This is best done with **smart public-private partnerships that support innovative actions**.

Innovation economics holds that although there is equilibrium in some markets at some times, in **a growing share of markets in the new knowledge-based economy, equilibrium is a fleeting moment**. Rather, markets are dynamic and constantly roiled by entrepreneurial entry, disruptive technologies, political and social upheavals, changes in trade patterns, and more, never settling down into equilibrium. The lack of equilibrium is especially characteristic of industries with higher levels of change and innovation. Moreover, innovation economists believe that market disequilibrium leads not to economic inefficiency but growth and progress.

Finally, innovation economics recognizes that the **information available to economic actors is incomplete and uncertain**, rendering calculated "rational" decisions difficult, particularly within the confines of a neoclassical price model. Innovative activity, particularly if it involves a high degree of novelty, typically involves uncertainty, whereby outcomes and their associated probabilities are not known at all, rather than by risk, where the outcomes are known with a calculable probability. When the economy is characterized by uncertainty—as it is today, for example, with respect to energy prices and the environment—price signals alone are not the best guide to decision making. In an economy with more markets in disequilibrium, the old allocation models no longer provide adequate guidance, and relying on price signals alone to drive innovation is not enough.

Thus, successful innovations are based on knowledge about users' needs and about the value of the innovation to users. In this sense, smart innovation policies try to fill what is fundamentally a knowledge gap. Thus, it is difficult, if not impossible, for individuals and firms to make effective decisions under conditions of uncertainty relying only on price signals.

Consequently, innovation economics focuses on facilitating innovative actions and supports complex innovation systems with a variety of policy tools in order to move the economy in a strategic direction. Innovation economics appreciates that the market is an efficient tool to drive economic growth and that government should correct market failures. However, contrary to the neoclassical doctrine, just letting markets work is not enough. Innovation economics views government intervention through a teleological lens, such that government support spurs the economy to achieve productivity and growth at the lowest possible societal cost. McKinsey Global Institute Senior Fellow Eric Beinhocker suggests that the role of government is essential given the interaction of technological innovation, social development, and business practice, and that government should create the institutional and policy conditions for effective economic evolution based on a series of goals.[12]

The doctrine of "innovation economics" reformulates the traditional model of economic growth and recognizes knowledge, technology, entrepreneurship, and innovation as primary factors for economic growth rather than as independent forces that are largely irrelevant in the prevailing doctrinal approaches to economic growth.

Economic Doctrines & Climate Change Policy

To date the United States has responded to the challenge of climate change with at best incremental and haphazard policies. Our failure to craft and implement a coherent climate change policy is principally rooted in our inability to agree on one economic doctrine.[13] Competing doctrines and reliance on the 20th century doctrines make it tougher to reach consensus on the most effective policy approach to climate change.

The assumptions of the three competing 20th century economic doctrines guide and are embedded in climate change policy solutions, from the analysis of the problem to the design and implementation of policy (see Table 1). Neoclassical thinkers propose that pricing carbon dioxide emissions (the main GHG), either through a tax or trading regime, should allow markets to effectively work out a solution; increasing the price of high-carbon energy *should* create space for entrepreneurs and innovative lower- and zero-carbon alternatives. At the same time, those guided by neo-Keynesian economics hedge that new carbon markets may not be all that efficient and are uncertain at best. They prefer a command and control approach that sets rules on the market (regulations) and provides subsidies to ensure a level playing field among low- and high-carbon energy sources. The conventional doctrines fail to understand that global warming and resulting climate change are more than conventional pollution problems, and that complexity, uncertainty, and risk create multiple market failures and limit the effectiveness of both traditional market-based tools and more recent command-and-control strategies.

Innovation economics focuses on more than market-mediated price signals, like a carbon tax. Innovation economics proposes that to confront the challenges that climate change presents, policy must address the market failures, uncertainty and risk for clean energy entrepreneurs, and the information asymmetries of today's energy markets. Although prices on GHG emissions are useful, they alone cannot lower GHG emissions to prevent global temperatures from rising more than two degrees Celsius by 2050. This would require policies for stabilization at 450 parts per million of carbon-dioxide-equivalent, approximately a 50 to 85 percent reduction in our current emissions.[14] As for regulating and subsidizing existing generations of renewable energy, innovation economics likewise recognizes that these measures do little by themselves to spur the innovation needed to create breakthroughs of affordable next-generation alternatives. Only a policy approach grounded in innovation economics offers the full range of tools needed to embark upon the difficult task of designing a new systematic approach to addressing the institutional hurdles of our currently muddled and disparate policy programs on climate change and clean energy.

Innovation economics offers a multi-faceted strategy—an innovation policy framework—that can address our global predicament with the use of a carbon tax to price GHG, complemented by investment in mechanisms and institutions that will spur clean energy technology research, development, and deployment. A recent poll showed that people increasingly believe that new technologies can solve global warming, up from 30 to 48 percent in the past two years.[15] According to Lord Nicholas Stern, former chief economist of the World Bank, "[t]he way forward to the low-carbon economy requires finding new ways of consuming and producing, and in particular replacing hydrocarbons. This means innovation and investment in new technologies and activities that can save resources while producing no greenhouse gases or actually removing them from the atmosphere."[16] However, the currently debated policies largely ignore this approach, or, in a neoclassical manner, reject backing any specific clean energy technology because "picking winners" interferes with the market and allocative efficiency.

The disagreement on policy solutions due to economic doctrine preferences is even more consequential given the massive scale of change needed to address global climate change. William Bonvillian and Charles Weiss characterize the energy sector as complex, deeply entrenched, and heavily subsidized.[17] The sector's current privately funded energy research and development spending accounts for less than one-half of one percent of industry revenues. This is dismal in comparison to the nationwide industry average (ten times that size) and two orders of magnitude less than innovation-intensive industries like IT or biomedical technology.[18] Bonvillian and Weiss argue that "we should not underestimate the difficulty of the process for introducing new technology at the massive scale demanded. In energy, this process has eluded us for the last four decades. These complexities underscore the need for a comprehensive new theoretical approach."[19]

The following sections describe how current climate policies adopt the principles and assumptions of leading economic doctrines and examine the advantages and constraints of these proposals in confronting the global challenge of global warming and climate change.

Neoclassical economics on climate change: carbon pricing or trading Permits

The principles and assumptions of neoclassical economics suggest the primacy of prices and markets as the sole organizing force for economic interaction. The less public policy interferes, the argument goes, the more efficient and in equilibrium they will be. As liberal neoclassical economist Alan Blinder argues: "Unless the market is malfunctioning, such tax-induced redirections of resources reduce economic efficiency. They are therefore to be minimized."[20]

However, the bar for establishing market malfunction is quite high for neoclassical economists; and in the case of global warming, the production of GHG is not a normal "good" that markets produce. GHG is an environmental externality, where the producer of a good emits GHG in the production process, but does not pay for the costs that GHG places on the environment, i.e. global warming. Neoclassicalists, therefore, frame global warming as a conventional pollution market failure. GHG are a negative externality amenable to a market solution, e.g., pricing GHG so that producers, consumers, or a combination of them pay for the costs. As neoclassical economist Stephen Holland suggests, "Emissions are generally modeled using one of three equivalent approaches: as an input in the production process, as a joint product which is a "bad," or as abatement from some hypothetical level, e.g., business as usual."[21] The decision on how to model the problem is a direct result of assumptions that will constrain the outcomes as well as policy solutions.

Innovation economics endorses government support of innovation and rejects the neoclassical economics depiction of innovation as an exogenous process that is solely responsive to price signals or that falls like "manna from heaven."

Even though conservative and liberal neoclassical thinkers agree on the basic principle of correcting market failures by charging for GHG emissions, their climate policies diverge based on their view of the appropriate role of government intervention in the case of a negative externality. Some conservative neoclassicalists prefer to completely free energy markets of any government intervention, while others propose that a direct carbon tax would produce the most efficient results. Many liberal neoclassicalists, on the other hand, recognize the limitations of a completely free competitive market and favor tradable carbon markets.

Conservative Neoclassical Approach to Climate Change: Deregulation and Carbon Taxes

The crux of the climate change debate to the conservative neoclassicalist is ensuring a limited role for government in addressing the production of GHG. Two conservative approaches to global warming and climate change dominate this basic viewpoint while upholding the basic principles of market-mediated prices and allocative efficiency.

The first, but less prevalent approach in the current policy debate favors complete deregulation and elimination of subsidies in energy markets to "let markets work." In this model, there is no need for government policy to correct a market failure by imposing taxes on GHG emissions; rather the solution is to reduce existing energy market distortions. J.D. Foster, an economist at the Heritage Foundation, stated as much in recent Congressional testimony: "Markets are not perfect. Markets make mistakes. And government has a modest but clear role to play in the process. But on balance and over time, market participants facing price signals undistorted by government policies make fewer mistakes, less costly mistakes, and more quickly correct mistakes. Consequently, private markets will generally allocate our nation's resources so as to produce the most value at the least cost."[22]

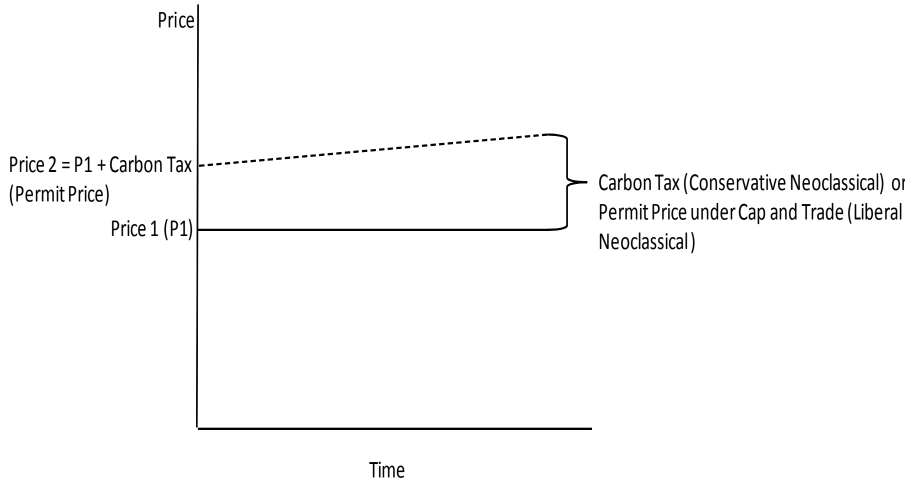
In an American Enterprise Institute (AEI) policy brief, environmental scientist Kenneth P. Green further explains this brand of conservative neoclassical policy.[23] He argues that decentralization, deregulation, and freeing markets will maximize U.S. adaptation to a dynamic, changing climate. The deregulation of electricity markets would result in the removal of energy subsidies as well as fuel and renewable power mandates so consumers would bear the full cost of energy consumption. Deregulation would free markets, and with higher prices in place, price-mediated transactions would more readily attain allocative efficiency. Higher prices would also incentivize both producers and consumers to press for greater conservation, more energy-efficient production processes, appliances, and devices. The Cato Institute's *Handbook for Policymakers* proposes much the same energy policy and opposes legislation on carbon dioxide emissions.[24] The Competitive Enterprise Institute also follows in this vein.[25]

Conservative neoclassicalists are not alone in recognizing that U.S. subsidies of fossil-fuel energy create unwise incentives to produce energy with high-carbon fuels. The U.S. Energy Information Administration calculated that fossil-fuel-specific energy subsidies were approximately $5.06 billion in 2007 in comparison to $2.37 billion for nuclear, wind, biomass, solar, wind, geothermal, and renewable.[26] The Environmental Law Institute had similar estimates for 2002 to 2008, with fossil fuels receiving $72 billion (versus $29 billion for renewable energy) in the form of tax breaks that aid foreign oil production, royalty relief, tax incentives, direct payments, and other forms of support to the non-renewable energy industry.[27] Yet, the dollar comparison does not depict the situation completely. The more adequate comparison would be on per unit of energy generated; by that standard, fossil-fuel subsidies are substantially smaller than those for renewables and other energy sources.

In reality, complete energy deregulation and elimination of all subsidies is politically unfeasible. In addition, although ending subsidies for carbon-based fuels will help and is advisable, simply letting markets work still fails to fully price the externality. Deregulation of energy markets alone would likely not create enough correct incentives to increase low-carbon energy usage, and with respect to subsidies for renewable energy, would actually increase the price of existing lower-carbon sources.

Recognizing these issues, most conservative neoclassicalists go further and suggest that policymakers not only eliminate subsidies but also impose carbon or GHG emissions taxes as an optimal market approach to correct for the pollution externality. The carbon or GHG emissions tax is calculated on the carbon emissions of energy sources (such as coal, oil, and gasoline). These are often referred to as a Pigovian tax (or effluent fee) named after the English economist Arthur Pigou who believed that government could internalize a negative externality with a tax. Proponents prefer the tax to occur "upstream" in the fossil fuel supply chain, such that the "tax is passed forward into the price of coal, natural gas, and petroleum products and therefore ultimately into the price of electricity and other energy-intensive goods."[28] Figure 1 depicts this dynamic, with Price 1 the original price of high-carbon fossil fuels and Price 2 the price adjusted for the carbon tax. The tax doesn't directly affect the price of existing or next-generation clean energy technologies.

Figure 1: Increasing the Price of Fossil Fuels



Proponents agree that such taxes are typically more efficient than other approaches, like cap and trade or conservation mandates "because they can encompass virtually all emissions sources with minimal administrative burden, thereby maximizing low-cost mitigation opportunities."[29] Advocates of this approach include Glenn Hubbard and Greg Mankiw, both former chairs of the Council of Economic Advisors under former President George W. Bush, Yale University economist William D. Nordhaus, George Mason University economist Tyler Cowen, and think tanks like American Enterprise Institute and Heritage Foundation.

Most proponents claim that government should phase in the tax, setting it low initially but increasing it over time (as depicted by Price 2 in Figure 1). Nordhaus' optimal-growth framework suggests that an optimal carbon tax rate will need to rise over time due to the fact that "emissions are efficiently allocated across time, which implies that low-cost carbon resources have scarcity prices…and that carbon-energy prices rise over time."[30] The rationale is that an increasing carbon tax rate gives businesses and industries time to adjust to price and to plan for investments that would bring about the technologies needed to meet the future tax schedule.

Neoclassical economists believe that a price on pollution (Price 2 in Figure 1) flowing through the chains of production, will not only reduce the use of high carbon fuels, but also spur innovation to identify low-carbon alternatives and make current clean energy sources more competitive. As an American Enterprise Institute report suggests, "a carbon tax would create a profit niche for environmental entrepreneurs to find ways to deliver lower-carbon energy at competitive prices…[and] serve to level (somewhat) the playing field among solar power, wind power, nuclear power, and carbon-based fuels by internalizing the cost of carbon emission into the price of the various forms of energy."[31] In short, according to the neoclassical doctrine, the new price of high-carbon energy will send the correct price signals and induce the appropriate producer, consumer and entrepreneurial behaviors.

Although some conservatives oppose a carbon tax because they fear it will lead to increased government spending, some conservative neoclassical economists suggest that neutralizing the effect of the carbon tax by allowing it to offset other existing taxes may help overcome some political resistance. Otherwise, in their view, revenue from new carbon taxes would just be available for additional government spending which would further distort economic activity and reduce incentives for growth. Heritage Foundation economist Dan Mitchell goes as far to suggest that "even if somehow government programs could be implemented at no cost, they would still harm economic growth."[32] The revenue-neutral option rids the market of such distortions. Two versions of this approach exist; every dollar collected via the carbon tax either: a) reverts back to U.S. residents, like a dividend, or b) phases out a dollar's worth of existing taxes such as payroll or sales taxes.[33] Either revenue-neutral option also blunts potential criticism that the carbon tax is another scheme to increase government revenues.[34]

James Hansen, Director, NASA Goddard Institute for Space Studies and an important early climate scientist, voiced support for the former option, stating that "[c]arbon fee and dividend is the base policy needed to move the nation forward to a clean energy future."[35] However, unlike more conservative supply-side revenue proposals discussed below, he embraces more of an innovation economics approach, suggesting that more is needed, such as building and efficiency standards, and public investment in improved infrastructure and technology development. Allan Sloan, *Fortune* magazine's senior editor, proposes a carbon tax with a dividend, to make it politically palatable. He calls for "a heavy tax on electricity, gasoline and other energy sources whose use you want to discourage... [and] make that tax refundable—at least quarterly, maybe even monthly—for people who can't afford it."[36]

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The second approach to achieving a revenue-neutral carbon tax system employs supply-side principles such that the lowering of taxes on labor and capital will decrease the price of the input factor and yield greater investment, productivity, and long-term economic growth, even with higher energy prices. Arthur Laffer, considered the father of supply-side economics, suggested the latter approach in his 2008 New York Times editorial with Representative Bob Inglis (R-SC): "We need to impose a tax on the thing we want less of (carbon dioxide) and reduce taxes on the things we want more of (income and jobs). A carbon tax would attach the national security and environmental costs to carbon-based fuels like oil, causing the market to recognize the price of these negative externalities. [B]oth Democrats and Republicans could support a carbon tax offset by a payroll or income tax cut."[37] Economist Gilbert Metcalf of Tufts University and a research associate at the National Bureau of Economic Research agreed and proposed Green Employment Tax Swap (GETS), seeking carbon tax neutrality through reduction in all workers' payroll taxes.[38]

Tyler Cowen extended the idea further and forwarded his proposal as an "Economic Idea #4 that voters need to hear." He called for the phase out of all forms of capital income taxation, including the corporate income tax, and their replacement with a carbon tax, including a gasoline tax. "Savings and investment boost economic growth, but when it comes to energy, global warming threatens as a major problem and our dependence on Middle Eastern oil damages our foreign policy."[39]

Even though AEI's Green believes that climate change requires a market approach with the least intervention and thus complete deregulation, he has also supported a revenue-neutral carbon tax, while noting that such a tax system is just an "effort to impose stasis on a dynamic system simply using more efficient means."[40] Green and his colleagues Steven Hayward and Kevin Hassett suggest that "using the revenues generated from a carbon tax to reduce other taxes on productivity (taxes on labor or capital) could mitigate the economic damage that would be produced by raising energy prices."[41]

Thus, the key defining characteristic of these conservative neoclassical proposals is to raise revenues through a carbon tax and use the money to reduce taxes on capital (and perhaps on labor). As discussed above, this is consistent with the conservative neoclassical economic doctrine, and in particular, with two key aspects of it: 1) government should do little to distort allocative efficiency, and 2) capital accumulation drives growth. With regard to the first, a carbon tax is less distorting than subsidies or than cap and trade, which falls on some emitters but not others. With regard to the second, reducing taxes on capital (e.g., reducing top marginal tax rates, capital gains taxes or dividend taxes) is supposed to spur more capital formation, which in turn should lead to faster growth. Likewise, reducing taxes on labor should spur more labor- force participation.

Unlike neo-Keynesians discussed below, neoclassicalists do not want a carbon tax climate policy for the purpose of creating green jobs, as recent comments by liberal neoclassical economist former Federal Reserve vice chairman Alan Blinder, now of Princeton University, illustrates: "There are good reasons to create green jobs, but they have more to do with green than with jobs. There is no reason on earth to think that spending money on green jobs is more effective than spending on other things."[42] Blinder believes that government should impose a gradually increasing carbon tax and do so just after the economic downturn ends, arguing that this will automatically create desirable green jobs.

Critique of Carbon Taxes as the Sole Solution

The neoclassical focus on price-mediated markets is rooted in the belief that government intervention into markets will most likely result in a worse outcome. Markets are important, especially at the microeconomic level, and can help ensure that prices usually match costs to promote allocative efficiency. Certain markets, especially those characterized by stability and slow rates of change, do tend toward equilibrium. The problem is that many other markets do not. In the presence of an externality, conservative neoclassicalists view the taxing of dirty fossil-fuel-based energy as more acceptable than other cap-and-trade regulatory measures, or than "picking winners" with a clean energy innovation policy. However, the neoclassical conservatives fail to recognize the limits of singular market-based approaches to climate change policy.

The characterizing of GHG emissions as a conventional pollution problem creates a number of problems. First, neoclassical theory suggests that the tax and resulting increase in high-carbon energy prices will reduce demand, and thus reduce output. Although individuals and organizations are rational and respond appropriately to incentives, they may not do so all the time. According to David Andress, T. Dean Nguyen, and Sujit Das, "entities who are willing to pay the price can continue to pollute and even increase their pollution," particularly if it is economically feasible to do so because the carbon tax is not high enough.[43] Also, unless government imposes carbon taxes consistently across all emitting sectors, this problem is exacerbated. And unless all nations impose the same level of carbon tax on the same sources, all firms and sectors will not face the same tax. Actually, nations could easily develop into GHG havens, which would then require an additional policy mechanism/government intervention, like the reverse tariff present in some cap-and-trade legislation discussed below.

Second, uncertainty about carbon-price sensitivity and what an "optimal price" should be raises the probability that emitters will continue to pollute under a market solution. Determining what the tax should be to achieve climate goals or to match external costs is difficult. For example, Nordhaus' 2010 DICE/RICE models indicate that a price on carbon should be in the range of $40 per ton, much greater than his 2005 model predicted ($17 per ton) and equivalent to 5 cents per gallon of gasoline and one-tenth of a cent per kilowatt-hour of electricity.[44] Paul Krugman, a noted liberal neoclassical economist, explains the difficulty succinctly: "you can't put a price on something unless you can measure it accurately, and that can be both difficult and expensive."[45] Consequently, the variability in these estimates makes it difficult to assign the "right" price to GHG emissions.

Third, making the carbon tax revenue-neutral is somewhat problematic. In theory, as carbon prices increase, producers and consumers will change their behaviors, and in the long run carbon tax revenue would decrease if tax rates are not increased. Most tax proponents do not explore this aspect, and others argue that "as utilities install more costly low-carbon technologies to avoid escalating carbon taxes, consumers lose the carbon tax rebates. However, they still see their electricity costs increasing as utilities include the cost of carbon mitigation in consumer bills. Ironically, low-energy consumers are better off with the rebated carbon taxes."[46]

Related to the desired market response is the neoclassical belief that markets and not governments are best at determining innovation trajectories to solve a problem. The major advantage of a carbon tax, they argue, is that business and entrepreneurs will pick the winning low-carbon technology substitutes for fossil fuels. Neoclassical conservatives do not support the subsidization of either renewable energy or of research and development of next-generation green energy technologies since this would result in picking winners and inject perverse incentives into the market. Instead, market winners in a carbon-priced market receive the blessing of venture capital and credit markets for the level of investment for research and development (R&D), demonstration, and deployment required to push the clean technology through the commercialization process to market. Once the "right" carbon price is set, the magic of price-mediated markets alone will produce the most efficient clean energy alternatives.

In this view, the clearing of energy markets produces allocative efficiency across all related markets, and the necessary innovation to produce clean energy substitutes should be the outcome. Many neoclassical climate models just assume technological change will occur or treat it exogenously, and most of these models are extremely sensitive to the rate of technical change. Neoclassical proponents suggest that carbon pricing will deliver better technologies. However, as the fourth problem, such automatic clearing of markets based only on a change in the price of carbon ignores the presence of other market failures associated with innovative activity. Unfortunately, innovation is more problematic than neoclassical models suggest and will not fall like manna from heaven.

If higher carbon prices are really the key to spurring change, then we should see clean energy innovation in nations with higher carbon prices. But we don't. In many European nations, the price on carbon dioxide for transportation fuels is over $200 per ton, which is the amount reflected in their overall transportation fuel taxes. This is at least 5 to 10 times higher than the cost suggested by many neoclassical proponents of carbon taxes.[47] Europeans do drive smaller cars and drive less than Americans, but only some of this is attributable to higher tax. Most drove less before the imposition of high fuel taxes, and the density of Europe has made it more amenable to transit and walking. Small, medieval urban streets make large cars impractical in many parts of Europe. Moreover, the higher tax certainly has not induced Europeans to switch to electric cars. In fact, there are virtually no electric cars in Europe. The reason is simple: price signals lead to behavior change only when there is a viable substitute. Europeans, like the rest of us, will drive electric cars when there are better batteries and the infrastructure that supports electric vehicles. If beef suddenly tripled in price this past summer, Americans would be grilling a lot more chicken. Preferences aside, there is a less expensive substitute for beef. This is not the case when it comes to energy alternatives. Electric cars, for example, are still at the prototype stage and priced well out of reach for most U.S. consumers. Without the $7,500 tax credit, the Nissan Leaf will start at $32,800, while the Chevrolet Volt will be $41,000, and the lauded Tesla Roadster is a luxury at $109,000. Even those who can afford these vehicles face an inadequate infrastructure for wide-ranging use.

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Innovation is a complex process, and price alone will not induce all types of innovation in similar ways. Economist Vernon Ruttan of the University of Minnesota showed that price was certainly a factor in what he called "induced innovation;" however, he was largely referring to incremental innovation and engineering advances that are industry led, shorter term, and therefore, more responsive to price and market signals.[48] Induced innovation will be very important to energy technologies like solar photovoltaic that have been around for years and that focus on incremental advances to drive down price. In contrast, next-generation clean energy innovation will require radical or breakthrough technologies, often coined "pipeline innovation," which is long term in nature and less price sensitive at the R&D stages. To complicate the process further, existing innovation systems (rules, regulations, culture, etc…) as well as information asymmetries, uncertainty, risk, technology-path dependency, chicken-or-egg externalities, and a host of other "failures" affect the actions of innovators and entrepreneurs in the market. Specifically, entrepreneurs in the research and development phase encounter great uncertainty in market conditions. Couple this with the fact that pipeline innovation requires pushing a breakthrough idea through the valley of death—the phase in the development of technologies between research and commercial introduction in the marketplace—to translate it into a usable, market-worthy option. Thus, policies to enable innovations systems must overcome multiple of stumbling blocks.

In addition, a classic market failure that potential entrepreneurs of breakthroughs encounter is the knowledge externality. Innovators generally, and clean-energy innovators in particular, recover only a portion of the benefits their technologies produce. Innovation economists Phillipe Aghion, David Hemous, and Reinhilde Veugelers argue that most companies make the rational business decision to under-invest in fundamentally new green technologies, preferring to "free ride" off existing dirtier technologies that are cheaper.[49] They, as well as others like MIT innovation economist Daron Acemoglu, claim that when climate change policy includes only a carbon tax, the market will pick the cheapest existing lower-carbon technology. Entrepreneurs will choose to make incremental improvements to existing technologies rather than invest in the development of next-generation clean technology. The productivity gap between dirty fossil fuel and next-generation clean technologies will become even greater than it was before a carbon tax, and, according to economists Philippe Aghion, David Hemous, and Reinhilde Veugelers, the widened productivity gap "means that a longer period is needed for clean technologies to catch up and replace the dirty ones. As this catching-up period is characterized by slower growth…delaying action is costly."[50] Thus, a climate change policy that includes only a carbon tax results in reliance on existing low-carbon technologies that will slow our reduction in emissions and fail to generate the 85 percent reduction in carbon emissions per unit of output that, according to the Intergovernmental Panel on Climate Change, the planet requires by 2050.[51]

A carbon tax has considerable merits in that it is the most efficient single mechanism for setting a price on carbon. Such a tax across all sectors in a market, perfect information and rational actors, could lead to greater innovation and commercialization of clean energy. However, as a sole solution to climate change it ignores a series of other market failures that are especially pervasive in the present the energy sector. As described above, unless government crafts a clean energy strategy and co-invests in clean energy innovation, the carbon tax will more than likely support current "dirtier" low-carbon technologies instead of needed zero-carbon alternatives. This has global implications. If the market does not respond optimally with affordable clean technologies, the lack of adequate substitutes will most likely drive heavy polluters' production – and their jobs – offshore to nations where carbon taxes do not exist or are lower. The generated "carbon leakage" in turn hurts the global climate.

Furthermore, a global solution to climate change requires affordable clean technologies for countries that do not have the political will to impose carbon taxes. With the world's population forecasted to increase from 6.7 billion to 9 billion by 2030, global energy consumption and GHG emissions could effectively double. Even if the United States somehow finds the political will to impose high, or even moderate carbon prices, this does not address the global challenge. The only way it could do so is by spearheading the development of clean energy alternatives that are lower priced than conventional carbon-based fuels sources. As neoclassicalists argue, it is irrational for economic actors to pay more for clean energy than they would for dirty energy. Likewise, it is irrational for individual nations to impose carbon taxes unless the majority of nations do so at the same time since the costs are borne nationally, while the benefits are global. And, as discussed above, carbon taxes do not lead to the development of the most efficient, lowest-cost and globally affordable clean energy alternatives.

Table 1: Comparison of the Economic Doctrines on Climate Change

Factor	Neoclassical Economics			
	Conservative neoclassical ("supply-side") doctrine	Liberal neoclassical doctrine ("Rubinomics")	Neo-Keynesian Economic Doctrine	Innovation Economics Doctrine
Locus of economic growth	Supply-side (individuals and organizations)	Supply-side (individuals and organizations)	Demand-side	Supply-side (organizations, entrepreneurs, and "prosumers")
Principal economic policy goal	Growth and managing the business cycle	Efficiency and managing the business cycle	Equitable distribution of wealth to achieve social policy objectives	Growth and innovation
Key economic process	Allocative efficiency	Allocative efficiency	Consumer demand, full employment	Productive efficiency and adaptive efficiency
Organizing principles	Price-mediated markets in general equilibrium; complete information; individuals respond rationally to maximize self-interest	Price-mediated markets in general equilibrium; complete information; individuals respond rationally to maximize self-interest	Government-controlled markets; protect social good	Complex institutional systems with uncertainty and market disequilibrium; information is incomplete and uncertain
Organization of government	Limited	Focused on the basics	Big bureaucratic government	Reinvented government and increased reliance on quasi-public organizations and public-private partnerships
Climate Change	Carbon tax (revenue neutral), deregulation of energy market	Cap and trade, with emphasis on trade	Carbon caps, direct regulation, and subsidies	Clean energy innovation strategy to include carbon tax and research and development policies for clean technologies

Liberal Neoclassical Approach to Climate Change: Carbon Trading

Liberal neoclassical economists agree with their conservative brethren that price-mediated markets are the ideal allocation mechanism. Yet unlike the conservatives, who are wary of government intervention, liberal neoclassicalists justify a stronger role for government. Prominent neoclassical economist Paul Krugman suggests that "When there are 'negative externalities'—costs that economic actors impose on others without paying a price for their actions—any presumption that the market economy, left to its own devices, will do the right thing goes out the window."[52] However, the achievement of social goals should occur through "aftermarket" interventions. Like a good neoclassicalist, he continues "we should let markets do their job, making efficient use of the nation's resources, then utilize taxes and transfers to help those whom the market passes by."[53]

The liberal neoclassical approach recognizes the need for government to correct for energy-production by-products of GHG emissions. Like conservative neoclassicalists, they believe that higher energy prices will lead to more supply and less demand, but in the pursuit of equity they are less willing than conservative supply-siders to eliminate regulatory protections (i.e., permit offshore drilling) to expand supply. And they are somewhat more willing to consider government support for particular energy technologies, especially if the support is limited to basic research. Their major difference with conservative neoclassicalists is that they want to rely on market forces, not through carbon taxes but through GHG emissions trading, often referred to as a "cap-and-trade" regime, which is basically a government-facilitated quasi-market that is intended to correct for the GHG externality.

The ''cap'' sets a nationwide limit on GHG emissions that decreases over time. Although both a cap and a carbon tax should reduce emissions, liberal neoclassicalists support the cap-and-trade regime because they see the trading mechanism, backed up by the gradually decreasing cap, as providing more assurance of reaching climate change goals while still reaping the benefits of market-based allocation efficiency.

Still, the determination of an appropriate cap is essential, and similar uncertainties come to play in reaching an emissions goal as in setting a carbon price. Krugman explains: "If the government imposes a pollution tax, polluters know what price they will have to pay, but the government does not know how much pollution they will generate. If the government imposes a cap, it knows the amount of pollution, but polluters do not know what the price of emissions will be."[54] Consequently, the ''trade'' mechanism allows the price of polluting to emerge based on the cap, or number of carbon permits conveying the right to emit a specific volume of carbon or GHG. Environmental policymaker Geoffrey Styles demonstrates the importance of trade. Consistent with the conservative neoclassical view, he states: "…I have little doubt that a blue-ribbon panel of economists, scientists and engineers could come up with a reasonable estimate of the level of carbon taxation required to reduce emissions by the desired amount..." But in liberal neoclassical form, he adds, "I have much more confidence in the logic of setting the desired level of emissions reduction in each year, and then allowing the price to emerge from the interaction of those whose livelihoods depend on meeting these limits, in real time."[55] Thus, liberal neoclassicalists argue that the higher costs of emissions resulting from a cap will reduce emissions, and that the trading of permits will lower the cost of attaining emission goals because it will let the market decide which emissions reductions should be prioritized.

For market transactions to reduce GHG under cap and trade, the number of allowances should be small, increasing the price of the right to pollute. In Figure 1, above, Price 2 under cap and trade reflects the increase in the cost of fossil fuels due to the cost of obtaining the permit to pollute. Over time, the decreasing number of permits should increase the price of obtaining the permit; again, the cap has no direct price effect on clean energy technologies. A more conservative cap-and-trade regime would have government selling permits to firms that emit the pollution, and the market determining the most efficient distribution of permits. On the other end, in a liberal regime the government would allocate the "allowances"—a more appropriate name given the difference between selling and granting the permits—based on current emission profiles or industrial sectors. In terms of U.S. climate policy, the recent cap-and-trade Congressional proposals include some combination of the two, as in the American Clean Energy and Security Act (ACES) of 2009 that passed the House of Representatives and the more recent, failed proposal of Senators John Kerry (D-MA) and Joe Lieberman (I-CT), the American Power Act (APA) of 2010. [56]

The determination of how to distribute allowances is contentious given how political factors influence the decision process, although this is similar to how politics can affect decisions about the carbon tax (e.g., tax rebates may be given preferentially to groups that are supportive). Neoclassical economics refer to this as another failure, but not a market failure; rather, it is a government failure called rent-seeking. Government determining who gets the allowances leads to lobbying and waste of resources which can further "distort" the market. Krugman points out that a carbon tax imposes costs on the private sector and generates revenue for the government, while a cap-and-trade regime "is a bit more complicated. If the government simply auctions off licenses and collects the revenue, then it is just like a tax. Cap and trade, however, often involves handing out licenses to existing players, so the potential revenue goes to industry instead of the government."[57]

Along with political factors, liberal neoclassical principles also shape the distribution of incomes, as the doctrine is more comfortable with greater government intervention to achieve equitable outcomes among income groups and regions. An AEI report from conservative neoclassical economists Kevin A. Hassett, Aparna Mathur and Gilbert E. Metcalf suggests that the lifetime incidence of a carbon tax on household consumption was distributionally neutral across regions.[58] Liberal neoclassical economists Daniel Burtraw, Richard Sweeney, and Margaret Wells at Resources for the Future countered this finding in their analysis of a cap-and-trade regime. They found that the distributional effects were larger based on an annualized incidence, which magnifies disparate impacts among income groups and regional differences. This is in contrast to the lifetime incidence analysis that tends to minimize such impacts.[59]

Current proposals address each of these disparities. ACES and APA provide more free allowances to geographically-concentrated, high-carbon utilities' sectors to manage regional disparities. For example, the cap on coal-based energy providers/producers would require them to reduce carbon emissions, and providers would be able to trade credits among themselves and with other energy producers. With regard to regional household disparities, those in regions that would pay lower energy rates would also receive proportionately lower payroll tax reductions or direct distributions of revenue—often referred to as a "cap and dividend" as seen in Senators Maria Cantwell's (D-WA) and Susan Collins' (R-ME) Carbon Limits and Energy for America's Renewal (CLEAR) Act.[60]

Over the past two decades, the cap and trade approach to climate change has attracted a number of liberal neoclassical thinkers who once preferred carbon taxes and who now see the "trade" portion of cap and trade as an appealing alternative to pure command and control regulation. Liberal neoclassicalist Lawrence Summers, Director of the National Economic Council and outgoing Assistant to President Obama for Economic Policy, previously stated his preference for "carbon and/or gasoline tax measures to permit systems or heavy regulatory approaches because the latter are more likely to be economically inefficient and to be regressive."[61] But given the Obama administration's ruling out of a carbon tax, Summers suggests that a cap-and-trade program is a workable solution if it includes an escape clause when prices rise too quickly. Other liberal neoclassical proponents include Paul Krugman, Gene Sperling (the former head of President Clinton's National Economic Council and now Adviser to Treasury Secretary Timothy Geithner), and Peter Orszag (former director of the Office of Management and Budget and former head of the Congressional Budget Office); and organizations like the Center for American Progress (also home to some Neo-Keynesians), the Progressive Policy Institute, and the United States Climate Action Partnership.[62] [63] [64]

Critique of Cap-and-Trade Regimes

The "trade" portion of cap and trade is the product of the neoclassical belief that price-mediated markets will result in firms reacting rationally to the price on carbon, and some of the time this will occur. The liberal neoclassical doctrine's embracing of cap and trade assumes that all polluters face differential marginal costs to reduce their emissions. However, each polluter will compare the cost of a permit against the cost of reducing carbon emissions. If the incremental cost of emissions reduction is less than or equal to the permit cost, polluters will reduce emissions. If not, and it is profitable for the firm to continue doing "business as usual," it will buy permits to cover emissions from other firms that can cut emissions at a lower cost. The assumption is that the latter will undertake more abatement relative to firms facing higher costs. Thus, in contrast to the neo-Keynesian "cap" regime, the trade-enabled "market" in cap and trade determines which firms make deeper cuts to their emissions and which make shallower or no cuts.

There are several problems with cap and trade, many of them similar to the problems of a carbon tax. First, to the extent that proponents favor it because it imposes a cost on GHG emissions, it faces the same problems as a carbon tax regime, which is also supposed to induce low-cost compliance. In particular, solving global climate requires the development of low-cost, ubiquitous clean energy. Cap and trade and carbon taxes assume that this will simply happen.

Second, cap-and-trade regimes also encounter information asymmetry and uncertainties as to the appropriate cap. As discussed above, cap and trade "requires a considerable amount of information and expertise to get the emission-allocation process right, creating more room for error and exposure to political pressure."[65] It also requires government to design new institutions and give power to some organization to administer the trading system. The level of government intervention is what leads conservative neoclassical economists to believe that "cap-and-trade is too cumbersome to administer and could lead to speculators distorting the emissions trading market."[66] Regulators face great uncertainty in setting the cap, just as they would in setting the carbon tax level, because they do not know whether the benefits of reducing carbon emissions are higher or lower than originally anticipated.[67]

Much of the U.S experience with cap and trade builds off its acid rain experience and the market-based abatement of sulfur dioxide under the Clean Air Act amendments.[68] As Krugman stated, "The bottom line, then, is that while climate change may be a vastly bigger problem than acid rain, the logic of how to respond to it is much the same. What we need are market incentives for reducing greenhouse-gas emissions—along with some direct controls over coal use—and cap and trade is a reasonable way to create those incentives."[69] The problem is that acid rain and climate change are really not that comparable, particularly in scale and technology. Unlike GHG's global warming effect, acid rain was more geographically concentrated. Only one sector, coal-fired power plants, fell under the cap. And most pertinent, mitigation technologies to achieve reductions existed, enabling plants to either switch to low-sulfur coal or install scrubbers that captured and sequestered sulfur dioxide.

One part of the acid rain history is particularly instructive to today's debate: the significant price volatility of sulfur dioxide trading permits. This price volatility will likely be repeated under any proposed GHG cap-and-trade regime given the breadth of GHG-producing sectors that will put pressure on permit prices. With the supply of permits limited, demand for permits will likely vary over time due to changes in the demand for energy and natural gas prices. The industrial and geographical scope of the problem coupled with volatility of permit prices further increases uncertainty, particularly for innovators. As Resources for the Future economists Ian Parry and William Pizer note, the "volatility in permit prices may deter carbon-saving investments in capital or R&D that have high up-front costs: the long-term payoffs to a firm are very uncertain if the future price of CO2 is unknown….because firms can choose to abate less and pay more tax in periods when abatement costs are unusually high, and vice versa in periods when abatement costs are low."[70]

As discussed above in the carbon tax section, price volatility will tend to affect what types of lower carbon technologies may be adopted. The current price volatility in oil and gas markets is illustrative. The Clean Energy Group and Meridian Institute found that not only would the "cheapest existing low-carbon technologies and energy-efficiency measures (often called "no regrets" policies)" win in the market, but also that "any caps established are usually insufficient to drive deep and radical innovation; instead, they tend to drive incremental technical improvements and marginal cost reductions."[71] Similar to discussions above in regard to carbon taxes, the absence of viable, clean-technology substitutes creates a similar failure in a carbon trading regime. However, as a cap fails to decrease the total volume of emissions, the lack of low-carbon alternatives will likely increase the price significantly, and in turn decrease political support. Consequently, only more fundamental technical improvements and significant cost reductions will enable the global economic system to shift away from carbon-based fuels. This is discussed more fully below in the innovation economics section.

Further, as Ted Nordhaus and Michael Shellenberger of the innovation economics-based Breakthrough Institute recently suggested, emissions caps offer no certainty in reducing in emissions. As they put it, carbon caps are often met with "a variety of mechanisms, overt and covert, to control the costs of complying with emissions-reduction mandates. These have included over-allocating emissions allowances, 'borrowing' allowances from future compliance periods, exempting critical industries from emissions-reduction requirements, allowing for the purchase of 'hot air' from former Eastern bloc nations whose emissions declined sharply after the collapse of the former Soviet Union, and the purchase of carbon offsets from developing economies in lieu of actual emissions reductions."[72] In addition, the proposed regimes fail to capture all GHG emitters, and particularly small emitters for whom the costs of measuring emissions and engaging in trading are prohibitive; no matter how low a cap goes, they are a likely source of carbon leakage.

Solving global climate change requires the development of low-cost, ubiquitous clean energy. Cap and trade and carbon taxes assume that this will simply happen.

The initial trial period of the European Union's European Trading Scheme served as an example, when it gave away a large majority of permits in the first two phases (through 2013) while failing to cover all emitters. German bargaining resulted in heavy industry receiving free carbon credits as well as weaker penalties for noncompliance, and many other countries received similar arrangements.[73] As James Kanter of the New York Times noted:

> Its implementation has been marked by maneuvers and adjustments to the original framework that have yielded significant cost benefits to many of the continent's biggest polluting industries. Meanwhile, the amount of CO2 emitted by plants and factories participating in the system rose 0.4 percent in 2006 and an additional 0.7 percent in 2007.[74]

Although the European Commission proposed a number of amendments to address these issues, such as including the chemicals and aluminum industrial sectors that were initially excluded, they are currently still in draft stage and would not be in effect before 2013.[75]

Thus, cap and trade alone cannot address the challenges and multiple failures that climate change policy must address.

Neo-Keynesian Economics on Climate Change: Carbon Caps, Direct Regulation, and Subsidies

Neo-Keynesians' beliefs in demand-driven economic growth and the subsequent equitable redistribution of wealth frame their three approaches to climate change: carbon caps, direct regulation, and subsidies. According to economist Jonathan Harris, neo-Keynesian thinking on climate change is suggestive of their macroeconomic view:

> The imperfections, asymmetries, and market failures which they see as leading to macroeconomic problems may often also be associated with environmental and

> resource abuses and social inequities. But the more radical macroeconomic formulation—that market economies are inherently prone to severe disequilibrium, and that informed social intervention is essential for a sustainable society—is closer both in spirit and in content to the radical critiques of "optimal" market outcomes and smooth economic growth which have been advanced by Herman Daly, Richard Norgaard, and many others associated with an ecological economics perspective.[76]

Neo-Keynesians address climate change and GHG emissions with the goal of reducing social and environmental inequities. In doing so, their focus is less market dependent than that of the other three doctrines. They give little thought to the question of how firms should respond to the need for reducing GHG emissions. Rather, the job of government is to tell them to do it. And for emerging industries like renewables, government should provide subsidies to enable them to compete with lower cost carbon-based fuels. In their view, cap and trade is really about the regulated cap on emissions, with the trading component as a side benefit. They also seek to cap emissions with direct regulation to increase the use of current alternative energy sources or energy-efficiency products, as with renewable portfolio standards, fuel economy standards, and energy-efficiency standards for buildings and industry. Finally, neo-Keynesians view direct subsidization of renewable energy as a means of reducing the cost penalty it now faces in the marketplace. These measures include feed-in tariffs, electric vehicle tax credits, and financial tools and incentives, like "green banks," revolving loan funds and "cash for caulkers," which seek to increase renewable energy adoption and induce energy efficiency. This policy toolbox reinforces neo-Keynesian focus on demand-driven growth because mandating the use of or subsidizing the supply of alternative energy will induce demand, which will subsequently and automatically further drive supply. Neo-Keynesian proponents include many environmentalists like James G. Speth, environmental lawyer and founder of the World Resources Institute, ecological economists Herman Daly and Juliet Schor, Joe Romm of Center for American Progress and ClimateProgress.org blog, Manik "Nikki" Roy of the Pew Center on Global Climate, journalist Lisa Margonelli, and organizations and think-tanks like Blue Green Alliance, New America Foundation, New Economics Institute, and the Levy Economics Institute.[77] [78] [79] [80]

Many neo-Keynesians prefer a government mandate on the upper limit of GHG emissions with a command-and-control policy response like a complete ban on coal-fired plants. But because GHG emissions are not localized, they are willing to consider allowing emitters to trade permits for these emissions. In part, they have embraced cap-and-trade policies to reduce political opposition and to make it appear that this is not just old-fashioned command and control regulation, but something market-based and, hence, more politically feasible. Neo-Keynesian support of a cap-and-trade regime may at first glance suggest that that they have accepted liberal neoclassical market trading solutions; however, this is only because they view cap and trade as a way to limit emissions. The institution designed to enforce the cap-and-trade system is a regulatory mechanism that emphasizes the cap, not the trade. Although Paul Krugman's roots are liberal neoclassical, his recent comments about the difficulty of pricing carbon reflect his transition toward more liberal neo-

Keynesian economics when he writes that "sometimes it's better simply to lay down some basic rules about what people can and cannot do."[81]

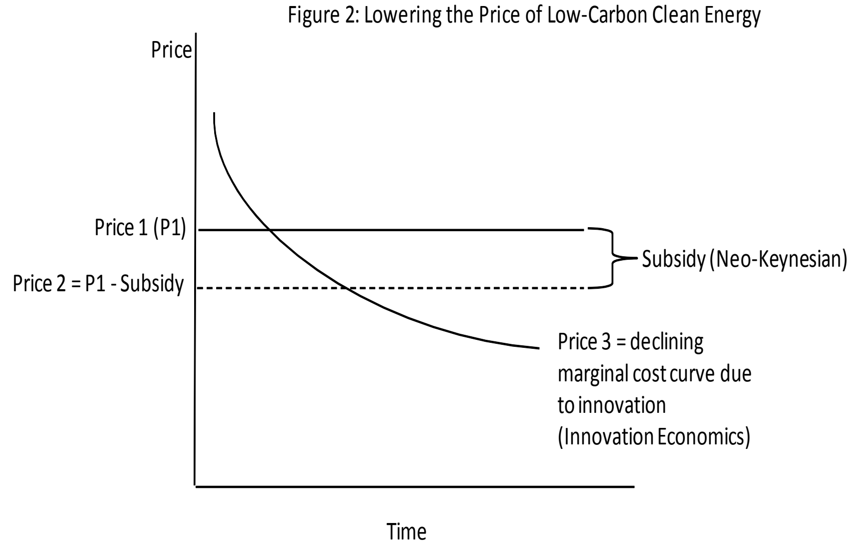
Neo-Keynesians believe that a cap-and-trade regime will open a window of opportunity for low-carbon alternatives to become competitive and grow in market share; however, in contrast to the neoclassical approach, the belief is that the market will simply not be allowed to produce high-carbon activities, and will therefore simply have to switch to low-carbon ones. Given that the latter are more expensive, in some cases much more expensive, neo-Keynesians see government subsidization of low-carbon activities as necessary to their competitiveness. Thus, in order to further direct the market in a clean energy direction, neo-Keynesians pair subsidies of existing technologies with direct regulation.

Direct regulation or mandates reflect neo-Keynesians' penchant for command and control regulation. This is why they support the requirement of a renewable energy (portfolio) standard (RES/RPS). RES and RPS impose a legal obligation on electricity supply companies to produce a specified fraction of their electricity from certified renewable energy. Certified renewable energy generators earn certificates for every unit of electricity so-produced, and they can sell these along with their electricity to the supply companies. To ensure compliance, electricity supply companies must pass the certificates to a regulatory body to demonstrate their compliance with their regulatory obligations. Thus this adds a level of regulation to the portfolio requirement to ensure that only certified providers of renewable energy are participating. Many states have these mechanisms, and they are currently proposed in federal energy bills. Senator Jeff Bingaman's (D-NM) proposed energy bill, American Clean Energy Leadership Act of 2009, would set a 15 percent national RPS by 2021 in conjunction with subsidies to be discussed below.[82] Even though Senator Richard Lugar's (R-IN) approach is not neo-Keynesian, his recently proposed Practical Energy and Climate Plan builds off of an RES base.[83] His diverse energy standard (DES) is looser, allowing any carbon-free energy standard beyond renewables; thus, coal with carbon capture and sequestration (CCS) and nuclear energy would qualify.

Other traditional neo-Keynesian regulatory approaches include federal rulemaking and energy performance standards on fuel economy, e.g., Corporate Average Fuel Economy (CAFE) and other efficiency standards. In the absence of climate change legislation, the U.S. Environmental Protection Agency (EPA) is finalizing a rule on GHG emissions. As EPA administrator Lisa P. Jackson recently explained, the "EPA has set common-sense thresholds for greenhouse gases that will spark clean technology innovation."[84] Examples of the latter include Senator Lugar's recent legislation containing provisions for federal- and national-building energy performance that targets federal and new residential and commercial construction and new fuel economy standards. These mandates are paired with governments matching grants for the $500 million per year through 2014, illustrating common neo-Keynesian combinations.

As the third major climate change tool, neo-Keynesians advocate assisting desirable industries with subsidies. In contrast to neoclassicalists, who see subsidies as distorting the market, neo-Keynesians view subsidies as simply one more tool government can use to achieve desired economic and social outcomes. They view subsidies as a way to help increase the supply of low-carbon energy alternatives and provide market pull or induced demand for existing renewable energy sources. Such subsidies decrease the consumer's price, as depicted below in Figure 2, with Price 2 falling below Price 1, the original price of the existing low-carbon technology. But absent technological innovation to drive down costs of renewables (as shown with Price 3), the subsidies must be in place in perpetuity.

Figure 2: Lowering the Price of Low-Carbon Clean Energy



In contrast to neoclassicalists, who see subsidies as distorting the market, neo-Keynesians view subsidies as simply one more tool government can use to achieve desired economic and social outcomes.

A favorite neo-Keynesian subsidy of current alternative energy production is the feed-in tariff (FIT). FITs are long-term contracts in which traditional electricity providers purchase renewable energy (solar, wind, geothermal, etc…) from renewable providers at an agreed-on price based on the cost of its generation. The conventional electricity provider subsidizes the renewable provider, which enables the conventional electricity generator to meet any requirements on the percentage of renewable energy it must offer in an RPS/RES or to reduce output of carbon emissions under a cap. FITs are prevalent in European countries like Spain and Germany. The Sacramento Municipal Utility District has recently signed its first purchase agreements for 60 megawatts of solar power.

A second neo-Keynesian subsidy tool is the tax credit. The American Reinvestment and Recovery Act of 2009 (ARRA) authorized the Department of Treasury to award $2.3 billion in tax credits for qualified investments in advanced energy projects to support new, expanded, or re-equipped domestic manufacturing facilities.[8586] The Section 48c clean technology production tax credits help support U.S. manufacturing capacity to supply clean energy projects with U.S made parts and equipment.

Beyond encouraging clean energy alternatives, neo-Keynesians also favor subsidies to incentivize behaviors like improvements in building and home energy efficiency with better insulation, windows, and solar panels. Senator Bingaman's proposed legislation (see above) provides grants to state-level lenders to support revolving loan funds for commercial and industrial manufacturers implementing technologies that improve industrial efficiency. Tax credits that target consumer behaviors support the past purchase of hybrids and present purchase of electric vehicles like the Chevrolet Volt. The Home Star program, which passed the House, is dubbed "cash for caulkers" since it would provide an energy tax credit for home renovations to improve energy efficiency as with better insulation. Even the stimulus' "cash for clunkers" rebate sought to incentivize buyers to replace gas-guzzling vehicles with more fuel-efficient models. And "feebates" encourage consumers to purchase fuel-efficient cars because the rebate rises with the level of gasoline savings.

A final category of neo-Keynesian subsidization more broadly encourages businesses that neo-Keynesians find desirable, for example, businesses that provide green jobs that also would spur clean energy through the demand-driven principle they embrace. Green businesses can cover a variety of business models, from renewable energy providers to service-oriented businesses that sell energy-efficiency plans and retrofits; additional benefits are realized if these businesses are rooted in disadvantaged communities. To facilitate the growth of preferred businesses, neo-Keynesians seek to subsidize their costs, as with tax incentives described above. In addition, they favor the creation of new financial institutions or "green banks," referred to as a clean energy national infrastructure bank, Green Energy Lending Authority, and Energy Independence Trust. Proposals for these "green banks" often include financing support, such as loan guarantees, for the near-term and wide-scale deployment of commercially-ready clean energy technologies and other financing tools for energy retrofit and conventional clean energy generation projects. The Coalition for Green Capital is a proponent of ideas that were presented in Representative Chris Van Hollen's (D-MD) proposed The Green Bank Act of 2009, including a board composed of the Secretaries of Energy, Interior, and Treasury, and Administrator of the Environmental Protection Agency.[87]

Critique of Neo-Keynesian Approaches to Climate Change

The Neo-Keynesian toolbox for climate change is based on a belief that government should direct the outcomes it wants, and that promoting policies that seek to decrease GHG is important. In this sense, cap and trade is just one instrument to begin restricting emissions, to be accompanied by further regulation and subsidization. As described in the liberal neoclassical section above, a number of issues plague cap and trade. However, none is more problematic than the neo-Keynesian view that the cap in cap and trade acts as a "guarantee" that emitters will produce less carbon emissions, particularly as the cap reduces emissions volume further over time. This thinking is deficient on two fronts. First, proposed cap-and-trade regimes do not place all emitters in all sectors under the regime. Second, the emissions guarantee works only if price is not important because a market intervention can either set a price or a quantity, but not both. Unless low-cost abatement solutions emerge, which is unlikely without a clean energy innovation policy, the guarantee of continuingly falling emissions will only lead to continually growing prices. If carbon were priced at some extremely high level, then needed GHG reductions would be possible. But the political support for cap and trade under that scenario would evaporate, as suggested by the failure of cap and trade legislation in the Senate.

The problem with the majority of the neo-Keynesian subsidies is that they are intended to make existing technologies cost competitive with carbon-based energy. They are not based on a clean energy innovation strategy where subsidies are strategically targeted to support the development clean energy sources that are cheaper than existing carbon based energy sources. Too often subsidies go to existing, but commercially premature and unviable "transition" technologies without a structured plan for long-term benefit. The consequence is that when the subsidies run out, the product is not cost competitive (as with the case of corn ethanol) and the supported industry asks for more. It is important not only to determine if these investments provide the next generation, zero-carbon solutions, but also to question whether the infrastructure needed to support successful commercialization and market absorption exists or needs support. Infrastructure bottlenecks reduce the potential of any clean technology option.

Neo-Keynesians subsidies focus more on the short term. Yet, focusing on "low hanging fruit" will mostly result in what innovation economics-focused William Bonvillian and Charles Weiss refer to as incremental innovations in conservation and end-use efficiency.[88] These innovations are often small improvements that are unlikely to produce clean technologies that cost less than coal or oil. However, without a strategy to address the need for dramatic clean energy innovations, too many potential solutions could lay fallow. This is due to the strong lock-in mechanisms of existing technologies; technological lock-in becomes even greater in the "complex, deeply entrenched, heavily subsidized energy sector."[89]

Neo-Keynesians don't really focus on the process of innovation. Their view is if you want something in the marketplace, either regulate it or subsidize it so it can compete. Markko Hekkert, a chemist and innovation professor at Utrecht University, suggests neo-Keynesians prefer to view energy technologies "through an 'environmental lens' and not through an 'innovation lens'….Meaning that focus was on high reduction of carbon at a low cost instead of how energy innovation really affected economic factors ([unemployment], GDP, growth, exports)."[90]

It is not that subsidies, per-se, are a neo-Keynesian strategy; as discussed below, innovation economists support subsidies. The issue is the target of subsidies. Subsidies like R&D investment or tax credits can be a technology-push strategy; not just a market-pull or induced-demand strategy. Figure 1 depicts this dynamic, with Price 1 as the original price of the technology and Price 2 including the market-pull subsidy. Without innovation to develop the next generation of cost-efficient technologies, subsidies are needed in perpetuity to make clean energy competitive with dirty.

In contrast, an innovation-focused policy that seeks to spur innovation and cost reduction helps drive down the costs of cleaner technologies in the long term (Price 3). With better and cost-competitive technologies, producers face no costs of compliance, and consumers experience a grid-parity alternative to fossil fuels. Such an innovation strategy will also lend itself to technological breakthroughs because it recognizes that innovation is a long process, with no certain time horizon, and is reliant on learning by doing. Breakthrough innovations are necessary to address climate change, and, as innovation economist Jan Fagerberg states, these "typically open up opportunities for a whole range of new innovations (without which such breakthroughs may in fact be of little economic significance)."[91] Neo-Keynesians don't think about the double role that subsidies can play as part of a strategy. They concentrate on the first and mostly modest market pull and ignore the second critical funding for targeted and effective investments to spur emerging technologies to scale and drive the cost curve down.

Likewise, the neo-Keynesian's performance-standards approach fails to drive innovation in any meaningful way, allowing existing, inferior technologies to win the part of the market that must meet the standards. In addition, according to Resources for the Future economists Parry and Pizer, "performance standards typically do not impose an economy wide carbon price and therefore fail to meet these conditions for efficiently distributing the burden of emission reductions across different firms, households, and mitigation options….[They] have a weaker impact on conservation than market-based instruments because, while lowering emissions per unit of output or use, they do not raise the cost of output or use to reflect resulting emissions."[92] The movement of current energy policy away from cap-and-trade to performance standards is falling into an inflexible, ineffective, non-innovative neo-Keynesian trap.

Too often subsidies go to existing, but commercially premature and unviable "transition" technologies without a structured plan for long-term benefit.

Innovation Economics on Climate Change: Carbon Tax & Clean Energy Innovation

The dominance of the neoclassical and neo-Keynesian economic doctrines in the climate change debate leads many policy makers to assume that the only options are setting a price on carbon through a tax or cap, regulating energy consumption, and/or subsidizing existing renewable energy sources. These doctrines offer restricted views of the policy problem and condone government intervention only for the sake of correcting an externality or ensuring equitable outcomes. Each doctrine's primary policy solution fails to recognize that addressing climate change entails correcting a significant array of market failures, including information asymmetries, risk, and uncertainty.

In addition, climate policy must confront a deeply entrenched, fossil-fuel-dependent, energy sector in which energy sources tend to dominate markets over long cycles. For example, coal usage started in the 1860s, but it was not fully integrated into the market until 1910; and while oil emerged as a potential energy source around World War I, widespread oil dependence didn't arise until the 1940s. Clean energy will face a similarly long path in gaining mass-market penetration unless we implement a comprehensive clean energy innovation strategy.

As explained above, the neoclassical response is to remove market imperfections or distortions while innovation economics embraces many of these imperfections as important sources of endogenous technological change and growth in a dynamic economy. Consequently, innovation economics policies seek to encourage certain neoclassical "impediments." Innovation economics recognizes the complexity of the sources of growth and the many institutions that confront companies seeking to develop clean energy innovations. Facilitating such innovative actions, improving productive and adaptive efficiency, and supporting a clean energy innovation system require a variety of policy tools to grow the economy in a strategic zero-carbon direction.

Innovation economics appreciates that the market is an efficient tool to drive change and that government should correct market failures impeding clean energy innovation. Like the neoclassicalists, holders of the innovation economics doctrine agree that getting price signals right, ideally through a carbon tax, is a necessary foundation. Clean energy technologies will always cost more initially, and without new functionality, consumers will not pay a premium for them. Thus, a price on carbon is essential to commercialization of new energy technology; however, a clean energy innovation policy is also a prerequisite because just letting markets work is not enough. Like neo-Keynesians, innovation economists agree that a proactive role for government is needed. But that role needs to be focused on creating a more robust clean energy innovation system, not simply mandating or subsidizing existing energy alternatives. In short, global climate change can't be solved without an energy revolution and that will not occur without a coherent and cohesive innovation system policy that spurs next-generation clean energy technologies to the point that they are cost competitive with fossil fuels. Neither price nor regulation alone can accomplish this goal while growing a productive, competitive U.S. economy.

In addressing the constraints of the dominant doctrines, innovation economics offers an alternative for climate change policy. Proponents include academics and economists like Daron Acemoglu, Phillipe Aghion, David Hemous, Reinhilde Veugelers, Paul Romer, Douglass North, F.M. Scherer, Paul David, and Dominique Foray, Lester Thurow, William Bonvillian, Charles Weiss, John Alic, and Richard Newell; and organizations and think tanks like the Brookings Institution, Breakthrough Institute, Clean Energy Group, Meridian Institute, and Third Way.[93] Moving to a low-carbon energy future will not be easy; however, innovation economics provides the correct frame to address climate change. The doctrine is concerned with dynamic processes of how markets develop and how organizations in markets innovate. Innovation is the means by which all types of economic actors can overcome limiting conditions, like the current reliance of fossil fuels and business-as-usual GHG emissions.[94] As innovation economists Thomas Grebel, Andreas Pyka, and Horst Hanusch clarify, "Innovation competition takes the place of price competition as the coordinating mechanism of interest."[95] Consequently, creating the environment for radical clean energy innovation will more directly confront the limiting conditions in current energy markets.[96]

To develop a coherent and cohesive innovation system policy that spurs next-generation clean energy technologies, it is essential to understand that innovation is not just science. The neoclassical doctrine recognizes that private markets don't naturally produce science and its accompanied R&D well; the deficiency in supply of this "public good" became an acceptable reason for public subsidization of scientific research. However, science isn't innovation. As innovation economist Jan Fagerberg states:

> Science is about expanding knowledge, not necessarily with a practical purpose in mind. Innovation is about combining different types of knowledge (not necessarily novel), skills and resources to solve practical problems and try the solutions thus obtained out in practice (usually with a view to commercial application). Science is mainly practiced in universities or other publicly supported research institutions whilst innovation is largely performed by private firms.[97]

Due to the differences between science and innovation, supporting the process of innovation and building an innovation system requires more than correcting a public-good market failure in the supply of science, as the neoclassical approach condones. Policies to create and nurture successful innovation systems recognize the different actors, forms of organizations, and incentive structures necessary to seed innovation, as well as the complex interdependencies across systems. In fact, even Fagergberg's allusion to the barrier among firms and universities is limited. Innovation systems are likely to rely on a hybrid model among university teams, startups, and smaller firms, much like Defense Advanced Research Projects Agency (DARPA) utilized and Advanced Research Projects Agency (ARPA-E) in the Department of Energy is currently funding.[98]

Given the range of challenges innovators face, clean energy innovation requires an innovation strategy. Beyond the "science as a public good" concept, markets for clean energy innovation are ripe with knowledge externalities. Although knowledge externalities are necessary to advance technology development, an inventor cannot completely accrue the benefits of information and knowledge surrounding the innovation and invention. Other "free riders" can use the information and benefit from utilizing it in their own offerings. Although publicly-created patent systems attempt to decrease the diffusion of benefits to others, the patenting process can be expensive and slow and still does not completely address knowledge spillovers. Thus, strategic government investment in clean energy innovation must address the externality. Although generalized support for research is important, it's not enough. Currently, U.S. policy fails to address in a cohesive and coherent manner even the conventional neoclassical failures in the clean energy innovation process.

An innovation-focused policy that seeks to spur innovation and cost reduction helps drive down the costs of cleaner technologies in the long term.

Innovation economics delves further and suggests that the current climate policy proposals fail to address the presence of information asymmetries and uncertainty in the innovation process. Information is usually incomplete, and although the response of innovators can be rational, they are bounded by what is known and how what they know is related to other pieces of information. Consequently, limited information and bounded rationality affect investment decisions due to the uncertainty of an innovation's future success—the impact may be too risky to garner anticipated returns. In clean energy, scientists, researchers, and would-be entrepreneurs are unsure that the United States will address climate change in any way that will increase provider and consumer demand for better clean technologies than already exist today. Instead of working toward the next generation, their efforts offer incremental improvements of the market's current offerings. A cohesive climate innovation policy must address these limits to develop the next generation of clean energy.

In cases where government does support clean R&D, it shies away from picking winners due to neoclassical guidance. Unfortunately, this also ignores a basic tenet of an innovation strategy. As Hekkert suggests, "new sustainable technologies tend to be more expensive and have lower performance measured along some dimensions than existing technologies."[99] The guiding rationale for innovation economists is that only with a commitment to clean-technology cost competitiveness will long-term gains be enough to address climate change. Supporting these winners is part of this process and will lead the United States beyond incremental improvements to existing technologies. A partial commitment to an innovation strategy came with the establishment of ARPA-E in 2009, which awards monies in transformational R&D, and the Department of Energy's 46 Energy Frontier Research

Centers (EFRCs), which involve universities, national laboratories, nonprofit organizations, and for-profit firms in basic- and advanced-discovery energy research.

Innovation economics also provides reasoning for why and how conventional government support should go beyond correcting market failures, and in due course commit to clean technology cost competitiveness. According to innovation economist Allan Gjerding, in place of prices, the "market must be endowed with inter-organizational arrangements in order to achieve coordinative efficiency in cases where there is not complete knowledge about the characteristics of new products and processes."[100] The doctrine recognizes that "what matters most for successful innovation is not so much the link with basic science, big public laboratories or universities, or IPRs [intellectual property rights] for that sake, but close interaction with users (demand), suppliers and competitors."[101]

Thus, the development and support of these inter-organizational arrangements or "networks" that encompass these interactions are essential to the clean energy innovation process. Economist John Barber explains that firms "gain various kinds of technology, knowledge, information, market access and other resources" from interactions in networks of "suppliers, customers, competitors, universities, research institutes, investment banks, government departments."[102] The sharing of information within and across networks depicts the complexity of innovation, and how coordination among network actors can increase productive and adaptive efficiency, which in turn can result in improved basic routines and the development of clean energy breakthroughs.

For example, government-supported clean energy innovation should facilitate networks and collaboration with incentives built into federally-funded research grants to universities and federal labs. Government contract managers making federal research fund awards should know what intellectual property is being developed and has potential; moreover, a process should be in place to increase communication, collaboration, and coordination among all technology transfer institutions. Moving ideas, people, money, facilities and equipment seamlessly among the collaborators (government, university, industry, NGO, foundation, etc.) is essential in a global, knowledge-based economy. Creating these partnerships would also go a long way toward facilitating commercialization through the development of a cluster of essential actors like research and business partners as well as specific expertise in economic development, financing, and regulation. These new networks will provide a foundation for a clean energy innovation system.

Several initiatives and proposals provide examples of building networks and driving collaborative clean energy commercialization: the Department of Energy's three energy innovation hubs consisting of large, collaborative teams of scientists and engineers that work together to pursue transformative clean-technology breakthroughs; the first interagency Energy Regional Innovation Cluster (E-RIC) focused on Energy Efficient Building Systems; and Brookings Institution's proposed energy discovery-innovation institutes, which would be a national network of regionally-based, energy discovery-innovation institutes (e-DIIs) to serve as hubs of a distributed research network linking the nation's best scientists, engineers, and facilities. [103] [104] [105]

A supportive clean energy innovation environment and resulting networks must also address specific characteristics of the energy sector, from its size and regulated nature to its lack of innovation and investment. Although the United States invented many of the clean energy technologies in wide application today, including nuclear, wind, and solar power, current private-sector energy R&D spending and innovation is miniscule.[106] It accounts for less than one half of one percent of industry revenues, which is only one tenth of the nationwide industry average and two orders of magnitude less than innovation-intensive industries like IT or biomedical technology.[107] Hekkert suggests that "[D]ue to the strongly regulated character of the energy sector, normal market dynamics do seldom take place. Incumbent companies have a large influence in the political debates and decisions regarding any change in the energy sector. Smaller entrepreneurial firms hardly have any lobby power that is necessary to create favorable conditions for their innovations. The success rate of these firms is therefore much smaller than under normal market conditions."[108] Any clean energy innovation strategy must support and enable clean technology entrepreneurs and markets to be more adaptive and overcome these challenges and conditions.

Although nurturing and management of the process of clean energy innovation is essential, innovation economics does not ignore the importance of pricing carbon in addressing climate change. The market is an essential complement to the design of a government-supported innovation strategy; however, the complexity of the climate change challenge requires a multiple policy tools approach. Pricing carbon is part and parcel to addressing the environmental externality and can also help provide revenues to support clean energy research, development and deployment.[109] But supportive innovation strategy cannot stop there. Tufts University environmental scientists William Moomaw and Judy Layzer recognize this in their support for carbon taxes and for dismantling "the web of policies that overwhelmingly favors fossil-fuel production and use and actively discriminates against new technologies and practices that would reduce harmful emissions….Similarly, policies that protect large, obsolete coal-burning power plants in the United States obstruct efforts to make a transition to newer, more efficient power sources, including renewables and distributed, combined heat and power systems."[110]

Innovation economics stresses that other tools must complement carbon pricing to establish an innovative clean energy system. Pricing carbon in combination with a clean energy innovation strategy promotes a long-term solution that spurs innovation, drives cost curves of clean technology downward (see Price 3 in Figure 2 above), and makes clean energy cost competitive with fossil fuels, without long-term subsidization.

Current research also supports this framework. Recent findings from innovation-minded economists suggest that optimal environmental regulation includes a carbon tax to control current emissions as well as research subsidies to influence the direction of research.[111] Acemoglu and coauthors state that an optimal policy relies "less on tax and more on direct encouragement of development of clean technologies."[112] Yale University economist David Popp proposes that market-based policies must focus on the long term because in the short term the cheaper and close-to-market alternatives will dominate. Consequently, long-term policy must direct basic R&D with investment tax credits and technology mandates, as well as recognize how R&D should also focus on commercialization and not just development.[113] A clean energy innovation strategy would adopt the long view and provide support throughout the innovation life cycle. Most technology transfer managers in universities and national labs claim that technology development gap funding for proof of principle or concept is both economical and essential to technology maturation, yet less than two percent of programs provide such proof-of-concept or principle support. A potential policy tool of a government clean energy innovation strategy would designate a certain percentage of all federally-funded research for technology development gap funding, diminishing some development barriers.

Carolyn Fischer and Richard Newell also suggest that long-term R&D strategies are essential to addressing climate change outcomes. They compare R&D subsidies for existing renewable energies to other climate policies (carbon pricing, mandates, performance standards, etc.) in terms of meeting climate goals, such as reducing emissions and reducing energy consumption. They find that subsidies for existing renewables performed much worse than other approaches; however, they acknowledge that this was because the subsidies prompted only incremental change in existing renewable technologies. The authors suggest that the outcome was a result of the "focus on reductions over the near-to-mid-term and incremental improvement of existing technology, rather than breakthrough technologies that might achieve deep reductions. It seems likely that R&D policies have greater salience in the latter context…"[114] They also conclude that multiple policies are important to meet climate goals; "We show that an emissions price alone, although the least costly of the single policy levers, is significantly more expensive alone than when used in combination with optimal knowledge subsidy policies."[115]

Currently, U.S. policy fails to address in a cohesive and coherent manner even the conventional neoclassical failures in the clean energy innovation process.

Aghion and his coauthors find similar cost savings.[116] An innovation strategy addressing price and innovation with its multiple market failures offers a dynamic approach that is also less costly in the long term due to investments that will drive the cost curves of producing zero-carbon energy to grid parity with fossil fuels. As part of the stimulus package, ARRA authorized the Section 48c clean technology production tax credits, discussed above. The Section 48c clean technology production tax credits offer an example of a coordinated government effort to spur private-sector innovation in clean energy manufacturing. The government should not only extend the program, but also modify it to make it a driver of clean energy innovation.[117] For example, it should include a criteria to reward projects that are likely to lead to greater exports and more breakthrough innovation

A government-supported clean energy innovation strategy would also seek to leverage other mechanisms like procurement to pull and push clean energy innovation. Several innovation economics thinkers recently proposed that the Department of Defense (DOD) do so. DOD is a major customer for energy-consuming systems and equipment, with its approximately 500 permanent installations and expenditure of $10 billion a year on liquid fuels. In addition, the R&D capacity of DOD is tremendous—30,000 engineers and scientists in R&D and procurement, an annual R&D budget of $80 billion, and over $100 billion spent on procurement. John Alic, Daniel Sarewitz, Charles Weiss, and William Bonvillian suggest that "the DOD thus has the incentives and capacity to be a smart and demanding customer for new energy technologies, as well as a test bed for new ideas such as high-energy-density electrical storage."[118] DOD procurement could induce demand, decreasing the uncertainties and knowledge spillovers that entrepreneurs face, and spur innovation in clean energy technology, creating a bridge to the critical next generation. In addition, procurement can also help leverage other government clean energy investments. For example, the ARRA's $1.5 billion investment in advanced battery manufacturing and production should result in 640,000 advanced batteries on the market in 2015.[119] If DOD would look to utilize this production, it could encourage competition and risk taking, as well as ensure appropriate safety requirements.

Innovation economics proposes that the failures of "command and control" policies, carbon taxes, and cap-and-trade systems emerge because the mandates and price mechanisms ignore the importance of creating a new foundation for innovation competition. Climate change is more than the lack of full pricing of fossil fuels, which is addressable with a carbon tax. An innovation economics framework focuses on the importance of subsequent action—spurring clean energy innovation that is cost competitive globally. Innovation economics recognizes that the private sector's full price of investing in innovations is not recoverable in any market exchange because it spills over to other producers and users who do not invest. The existence of these free-riders decreases the incentive to invest in R&D that would generate viable alternatives to reduce GHG, such as fully electric cars, affordable solar cells, and large-scale electricity storage devices. Thus, without directed government support, incremental technologies will be the only option. Innovation economists view a suite of policy tools as essential to confronting climate change and guiding the economy in a clean energy direction; carbon taxes, government support of clean energy R&D, and the creation of supporting institutions and networks are all critical in creating innovation competition and driving clean energy on a global scale.

CONCLUSION

In the 21st century's global economy, innovation and knowledge are the most important factors not only in driving economic growth, but in addressing climate change. U.S. policymakers need to recognize that sole reliance on neo-Keynesian regulation and subsidies or the conservative and liberal neoclassical carbon taxes and cap-and-trade regimes will not only fail to significantly decrease GHG emissions, but also fail to produce the kinds of needed low-cost clean energy technologies that can be adopted globally—particularly in the absence of regulation, carbon taxes, or subsidies in other nations. These approaches give short shrift to the importance of government policy creating an innovative foundation for clean energy technologies.

Lord Stern offers perspective on a limited, "business as usual" action:

> If the economy stops growing now and we continue with existing technologies, the current level of annual global emissions of close to 50 billion metric tons of carbon-dioxide-equivalent would imply atmospheric concentrations of close to 700 parts per million within a century, and entail huge risks….Those who say that low-carbon growth is too costly, and that we can continue with high-carbon growth, make the same mistake. They embrace a view embodying 'limited

> substitutability' and 'restricted scope for investment in changing technologies': they embrace the growth theories of the mid-twentieth century.[120]

Recently, Nordhaus and Shellenberger noted that a climate-technology consensus has emerged among academics like Steve Rayner, Gwyn Prins, Mike Hulme; organizations like Policy Exchange, and Institute for Public Policy Research (IPPR), and even the American Enterprise Institute; and private sector leaders like Bill Gates and executives from Xerox and General Electric as founders of the American Energy Innovation Council.[121] This consensus reinforces the need for direct investments to overcome the technology gap and make clean energy much cheaper. Moving forward on an effective climate change strategy requires that an energy innovation strategy grounded in the right economic doctrine: innovation economics.

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