EVALUATING THE COSTS OF TECHNOLOGY NEUTRALITY IN LIGHT OF THE IMPORTANCE OF SOCIAL NETWORK INFLUENCES AND BANDWAGON EFFECTS FOR INNOVATION DIFFUSION

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INTRODUCTION

New technology is among the most promising weapons in the fight against climate change. In particular, there is significant room for technological growth within the energy sector.[1] Sustainable—or "green"—energy innovations can improve energy efficiency, encourage energy conservation, or promote alternative fuel use.[2] To capitalize on this growth potential, the United States has adopted a number of pro-innovation policies, particularly within the Tax Code.[3] These are designed to incentivize both industry and consumers to develop, produce, and purchase fuel-efficient and alternative-fuel technologies. This Student Article will investigate how the design choices used in these policies may impact their efficacy. Specifically, this Article will evaluate the costs and benefits of a "technology-neutral" design.

"Technology neutrality," or "tech neutrality," means that a

1 *See, e.g.,* KEVIN B. JONES & DAVID ZOPPO, A SMARTER, GREENER GRID: FORGING ENVIRONMENTAL PROGRESS THROUGH SMART ENERGY POLICIES AND TECHNOLOGIES 1–2 (2014) (indicating that the energy sector lags behind other sectors in sustainable innovation, but that there is room for significant improvement in sustainable energy production).

2 Energy conservation and energy efficiency are both means of reducing our total energy consumption. Energy conservation means that consumers reduce energy consumption by limiting their use of energy services, e.g., turning out the lights more often. In comparison, energy efficiency means that consumers reduce energy consumption through more efficient usage, while maintaining the same level of energy services, e.g., using more efficient light bulbs. *See id.* at 9.

3 *See Technology Neutrality in Energy Tax: Issues and Options: Hearing Before the S. Comm. on Fin.* 111th Cong. 1 (2009) (statement of Gilbert E. Metcalf, Professor of Econ., Tufts Univ.) [hereinafter *Metcalf*], *available at* http://www.finance.senate.gov/imo/media/doc/042309gmtest.pdf ("The tax code has become an important instrument for energy policy over the past decade."). For example, the United States enacted an Alternative Motor Vehicles Tax credit in 2005. *See* Energy Policy Act of 2005, Pub L. No. 109-58, 119 Stat. 594 (2006) (codified at 26 U.S.C. § 30B).

policy does not favor any particular means of achieving the desired goal.[4] In other words, to be technology-neutral, a policy must equally support all methods capable of achieving this outcome. For example, suppose we are attempting to design a technology-neutral tax credit. To remain tech-neutral, the size of the credit would need to be based on desired outcomes—e.g., reductions in carbon consumption or greenhouse gas emissions—without regard to the innovation that accomplished it. The amount of the credit would be the same for any given reduction, regardless of which technology was employed. Within innovation policy, technology neutrality has become a guiding principle.[5] In particular, many currently proposed tax reforms embrace technology neutrality.[6] The Senate Finance Committee itself has suggested large-scale, systemic tax reforms that would make the tax code more technology-neutral.[7]

Technology neutrality's current popularity is not without merit; it has a number of benefits.[8] Most importantly, because tech-neutral subsidies do not advantage any one technology, the market is free to develop the most efficient response to the problem.[9] In comparison, policies that are not technology-neutral—referred to here as "technology-specific"—may entrench a few selected technologies.[10] These technologies are chosen by

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4 *Metcalf*, *supra* note 3, at 4 ("In a general sense technology neutrality means that our tax code does not favor one fuel over another."); Chris Reed, *Taking Sides on Technology Neutrality*, 4 SCRIPTED 266 (2007) (indicating that definitions of technology neutrality are often ambiguous, but that one of the essential elements is that laws and regulations should not "favour or discriminate against a particular technology").

5 *See* Reed, *supra* note 4, at 264 ("Technology neutrality has long been held up as a guiding principle for the proper regulation of technology.").

6 *See, e.g.*, Metcalf, *supra* note 3.

7 *See* STAFF OF S. COMM. ON FIN., 113TH CONG., TAX REFORM OPTION PAPER ON INFRASTRUCTURE, ENERGY, AND NATURAL RESOURCES 13 (2013) [hereinafter S. COMM. ON FIN] (suggesting technology-neutral reforms across a wide range of tax policies).

8 *See infra* Section I.B.

9 *See, e.g.*, National Electrical Manufacturers Association, to Kevin Brady, Chairman, and Mike Thompson, Vice Chairman, H. Comm. on Ways & Means, Energy Tax Reform Working Group 3–4 (Apr. 15, 2013) [hereinafter NEMA], *available at* http://www.nema.org/Policy/Documents/NEMA%20Technology-Neutral%20Energy%20Efficiency%20Tax%20Reform%20Proposal_House%20W%20and%20M%20April%2015%202013.pdf (indicating that their proposed policy is technology-neutral and encourages a range of technologies).

10 *See, e.g.*, *Metcalf*, *supra* note 3, at 8–9 (indicating that the technology-specific HEV tax is problematic because it does not provide incentives to find other ways to reduce emissions, such as improving the combustion engine); *AEE Calls for Reform of Energy Tax Code to Boost Innovation, Provide*

the government and may not always be the best possible solution.[11] Technology neutrality can avoid this undesirable outcome. Because of this, technology-neutral tax policies are extolled by academics, media, and policymakers alike.[12]

However, the analysis cannot stop here. Caught up in their enthusiasm for tech neutrality's benefits, many have not taken the time to analyze its costs.[13] This Student Article cautions that technology neutrality is not a panacea. Like all things, it has costs as well as benefits. Policymakers should evaluate these costs before adopting technology-neutral policies wholesale. With this goal in mind, this Article introduces some potential benefits of technology-specific policies. These benefits of technology-specific design should be counted among the potential costs of technology neutrality. By accounting for these costs, this Article sets the stage for a cost-benefit analysis of tech-neutral policies. In particular, this Article emphasizes the potential costs of tech neutrality on consumer adoption of green products.

To elaborate, the touted advantages of technology neutrality mostly impact industry, not consumers: research and development will span all possible solutions to the problem; better inventions will result. Less attention is paid to the impact that technology-neutral policies will have on end-users and their decision to adopt innovative technologies.[14] But the process of innovation requires more than just development of a new technology. In order for clean technologies to have a positive effect on the environment, they not only need to be invented, they must also be used.[15] If

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No Permanent Subsidies, AM. ENERGY ECON., (Apr. 15, 2013) [hereinafter *AEE*], https://www.aee.net/articles/aee-calls-for-reform-of-energy-tax-code-to-boost-innovation-provide-no-permanent-subsidies (arguing that favoring a specific technology distorts markets and disadvantages new innovations).

11 *See infra* Section II.A.

12 *E.g.*, Metcalf, *supra* note 3 (academic); NEMA, *supra* note 9 (industry group); *AEE*, *supra* note 10 (U.S. business group association).

13 *See* Reed, *supra* note 4, at 265 ("The desirability of technology-neutral regulation has become part of the general wisdom, and is rarely questioned.").

14 This is part of a larger problem; adoption issues are often overlooked in innovation policy discussions. *See, e.g.,* Robert Spencer & Mani Vadari, *Smart Grid: A Customer Challenge*, PUB. UTIL. FORT., Oct. 1, 2009, at 48, 50 ("Typically overlooked during discussions of potential smart-grid benefits, is how presumed adoption rates will be achieved and sustained.").

15 *See* Natalie M. Derzko, *Using Intellectual Property Law and Regulatory Processes to Foster the Innovation and Diffusion of Environmental Technologies*, 20 HARV. ENVTL. L. REV. 3, 40 (1996) ("[E]nvironmental technologies must pass successfully into the diffusion stage if the innovation is to become widely used and thus truly useful for society.").

policymaking fails to consider end-users, the benefits of technological advancements may remain unrealized.

This Student Article focuses on consumer end-users in particular. As compared to sophisticated firms and professionals, consumers may be more prone to cognitive limitations and social and psychological influences.[16] The theory of diffusion of innovations—a theory that spreads across myriad social science disciplines and studies the determinants of innovation adoption patterns—can illuminate the behavioral factors that promote adoption among consumers.[17] This Student Article uses insights from innovation diffusion theory to evaluate the impact of technology neutrality on adoption, using the Alternative Motor Vehicle Credit (AMVC) as a case study.[18]

Notwithstanding technology neutrality's expected benefits for industry research and development, diffusion theory indicates that there is reason to be concerned that tech-neutral policies may have a negative impact on consumer adoption and diffusion rates.[19]

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16 *E.g.*, Howard Latin, *"Good" Warnings, Bad Products, and Cognitive Limitations*, 41 U.C.L.A. L. REV. 1193, 1199 (1994) (citing HERBERT A. SIMON, MODELS OF BOUNDED RATIONALITY (1982)) ("People have severe restrictions on cognitive capacity, attention span, and time that preclude assessing all relevant considerations in a "rational" manner. Consumers cannot evaluate all dimensions of all product-related risks because they are subject to these 'bounded rationality' constraints, a term devised by Herbert Simon to denote the presence of intrinsic limitations on people's capacity to make optimal choices."); Norman A. Silber, *Late Charges, Regular Billing, and Reasonable Consumers: A Rationale for a Late Payment Act*, 83 CHI.-KENT L. REV. 855, 867 (2008) ("Inherent information processing limits that affect all of us, as a notable example, affect our ability to estimate probabilities accurately. Consumers are further limited in their ability to calculate and maximize their expected utilities; the deficiency exists because consumer choices are affected by external manipulative factors. . . ."); *see generally* GERD GIGERENZER & PETER M. TODD, SIMPLE HEURISTICS THAT MAKE US SMART (1999) (discussing the cognitive limitations that cause individuals to be less than perfectly rational).

17 Rogers provides the seminal work on the subject. EVERETT M. ROGERS, DIFFUSION OF INNOVATIONS (5th ed. 2003). For a more detailed discussion of innovation diffusion, see *infra* Section II.B.

18 *See* 26 U.S.C. § 30B (2006).

19 Note that other authors have already acknowledged that there can be a trade-off between promoting adoption and promoting innovation for some environmental policies. For example, if a regulation mandates a particular technology, there will be high levels of adoption, but innovation will be discouraged as the market is dominated by the mandated technology. *See* Derzko, *supra* note 15, at 41 (1996) ("Magat notes that although technology-based standards discourage innovation, they cause faster diffusion of environmental technology . . . ."). This Article suggests that the same trade-off exists regarding technology-specific design, even though there is no explicit

Tech neutrality's potentially negative impact on adoption stems from the fact that innovation diffusion is heavily influenced by the passage of information over social networks.[20] The fact that information is key to this process of innovation adoption is not particularly controversial. At the very least, end users must know an innovation exists before they can adopt. Less obviously, the source of information also matters. Studies of the diffusion of innovations reveal that face-to-face, peer-sourced information is important.[21] Mass communication through government agencies or commercial campaigns is often not sufficient to promote adoption.[22] Because social information is important, adoption often follows a snowball pattern—growth in the number of adopters increases other consumers' information about the product, encouraging still more adoption.[23] In short, diffusion is self-reinforcing.

Technology-neutral policies present two concerns in light of the importance of social network influences. First, when multiple, substitute technologies are released onto a market in which there is an existing, mature technology, adoption of both of the new technologies can be impeded.[24] When two substitute technologies

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mandate: the selection of a particular technology by government will promote adoption, while it may harm innovation.

20 *E.g.*, Renana Peresa, Eitan Muller & Vijay Mahajane, *Innovation Diffusion and New Product Growth Models: A Critical Review and Research Directions*, 27 INT'L J. OF RES. IN MKTG. 91, 92 (2010) ("Innovation diffusion is the process of the market penetration of new products and services that is driven by social influences, which include all interdependencies among consumers that affect various market players with or without their explicit knowledge."); William H. Redmond, *When Technologies Compete: The Role of Externalities in Nonlinear Market Response*, 8 J. PROD. INNOVATION MGMT. 170, 172 (1991) ("Word-of-mouth recommendations are known to exercise a powerful influence on choice outcomes when the purchaser has little personal knowledge or expertise in the area of decision-making."). *See generally* ROGERS, *supra* note 17.

21 ROGERS, *supra* note 17, at 175 ("All innovations carry some degree of uncertainty for the individual, who is typically unsure of the new idea's functioning and thus seeks social reinforcement from others of his or her attitude toward the innovation. The individual wants to know whether his or her thinking is on the right track in the opinion of peers.").

22 *See id.* ("Mass media messages are too general to provide the specific kind of reinforcement that the individual needs to confirm his or her initial beliefs about the innovation.").

23 *See id.* at 359 ("When the critical mass in the rate of adoption of an interactive innovation is reached, the percentage of all individuals' network partners takes a sudden jump, triggering a much more rapid rate of adoption thereafter.").

24 Tineke M. Egyedi, *On the Implications of Competing Standards*, *in* THE

compete for market share, it is known as a "Standard War," and it can slow adoption rates and even prevent the market from selecting the best technology.[25]

The second concern, visibility, is inspired by the case study of the AMVC. As it was originally formulated, the AMVC promoted Hybrid Electric Vehicles (HEVs), including the Toyota Prius. The Prius is an extremely distinctive and noticeable car.[26] This makes it easily observable, or "visible." Visibility has been shown to strongly influence adoption of green behaviors.[27] Because visibility is so important, a credit for the Prius and other HEVs may have encouraged adoption more effectively than a credit for less visible vehicles would have. In the case of the AMVC, it was Toyota's clever design that made the innovation visible. However, future technology-specific policies could be used to purposefully encourage visible innovations. In contrast, technology-neutral policies cannot target particular methods and, as a result, cannot control the visibility of innovations. Therefore, a switch to technology neutrality would eliminate the potential for policy choices that capitalize on visibility.

In light of these concerns, this Student Article provides a cost-benefit analysis of technology neutrality in the context of consumer goods, and in particular, environmentally sustainable technologies. To counterbalance the extensive attention given to technology neutrality's benefits, the focus here is on its potential costs, especially in light of behavioral influences on adoption choices. Section I describes technology neutrality and explains its economic benefits, introducing the AMVC as a case study for evaluating technology neutrality. Section II provides background

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PROS AND CONS OF STANDARD SETTING 12, 17–20 (Dan Sjöblom ed., 2010), *available at* http://www.kkv.se/globalassets/publikationer/proscons/rapport_pros_and_Cons_standard_setting.pdf.

25 *Id.*

26 *See* WILLIAM M. PRIDE & O.C. FERREL, MARKETING 207 (2010).

27 This influence has been alternatively attributed to social learning or a phenomenon called "conspicuous conservation." *See* Marco A. Janssen & Wander Jager, *Simulating Market Dynamics: Interactions Between Consumer Psychology and Social Networks*, 9 ARTIFICIAL LIFE 343, 393–94, 399 (2003) (indicating that social learning and conspicuous consumption are the two mechanisms usually used to explain the social aspect of market choices); Vladas Griskevicius et al., *Going Green to Be Seen: Status, Reputation, and Conspicuous Conservation*, 98 J. PERSONALITY & SOC. PSYCHOL. 392, 396–97 (2010) (explaining the theory behind conspicuous conservation and providing experimental support). For a full discussion of the importance of visibility, see *infra* Section III.B.3.

for the adoption issue, reviewing innovation diffusion and green decision-making theories. Section III evaluates the potential impact that technology-neutral policies could have on adoption decisions, in light of Standard Wars and visibility issues.

In its conclusion, this Student Article indicates that tech neutrality has costs as well as benefits. Which of the two—costs or benefits—dominates will depend on the context of the policy being considered. Generally, this Article suggests that there are likely to be costs to technology neutrality if the technologies being promoted are substitutes, because end-users will adopt only one of the technologies. Costs may be even greater if: (1) the technologies are long-term consumer durables; (2) the products are high cost; or (3) consumers perceive a high degree of uncertainty and risk. These factors will increase the information deficit that potential adopters face; in other words, they will increase the amount of information that consumers need before adopting or reduce the amount of information that they have access to. In addition to these conditions of increased costs of technology neutrality, there are also conditions under which technology neutrality's benefits will be reduced. Specifically, whenever "network effects"[28] are stronger, it is less likely that we can rely on technology neutrality to ensure the "best" technology dominates. With greater network effects, there is a greater chance that a Standard War could prevent adoption of the best technology.[29]

I. TECHNOLOGY NEUTRALITY AND ITS BENEFITS

A. *What Is Technology-Neutral?: The Chronometer Story*

Tax policy is a popular arena for technology neutrality arguments, so this Student Article will focus on technology neutrality in the context of the tax and transfer system and, in particular, the AMVC. To evaluate the costs and benefits of technology neutrality in the tax code, it is first important to understand the principle. Generally, a policy is considered technology-neutral if it promotes a specific end goal but does not favor any particular type of technology,[30] as illustrated by the

28 *See infra* Section III.A.3.

29 *See infra* Section III.A.3.

30 *See Metcalf*, *supra* note 3 ("In a general sense technology neutrality means that our tax code does not favor one fuel over another."); Reed, *supra* note 4, at 266 (indicating that definitions of technology neutrality are often ambiguous, but that one of the essential elements is that laws and regulations

"poster child" for technology neutrality—a 17th century clockmaker named John Harrison.[31]

Before the 18th century, sailors could not accurately determine their longitude at sea, so they could not calculate how far they had travelled. Ships had difficulty rationing and were more likely to be wrecked.[32] In 1707, two thousand men were lost in a shipwreck caused by the crew's inability to determine their longitude.[33] In response, the British Parliament established the Board of Longitude, tasked with supporting the development of better longitude measurement systems.[34] The Board issued a Longitude Prize in 1714: a £20,000 award for whoever could develop a method for accurately determining longitude at sea.[35]

Many on the Board expected the solution to be based on astronomy.[36] Specifically, the solution they anticipated was the

should not "favour or discriminate against a particular technology").

31 Alice Roberts, A True Sea Shanty: The Story Behind the Longitude Prize, THE OBSERVER (May 17, 2014), http://www.theguardian.com/science/2014/may/18/true-sea-shanty-story-behind-longitude-prize-john-harrison; *John Harrison Definition*, ENCYCLOPEDIA BRITANNICA [hereinafter *Harrison*], http://www.britannica.com/EBchecked/topic/256006/John-Harrison (last visited Aug. 7, 2014).

32 *See* Shahan Cheong, *Time in Motion: The Story of the Sea-Clock, or Harrison's Chronometers*, http://scheong.wordpress.com/2010/03/25/time-in-motion-the-story-of-the-sea-clock-or-harrisons-chronometers (last visited Aug. 7, 2014) ("Mariners were in constant danger of getting lost at sea due to not knowing where they were, how far they had travelled and how far they still had to go. On a ship at sea with limited supplies and limited time to find safe harbour, not knowing your position was a serious safety-hazard.").

33 *See* Royal Navy Museum Library, *Biography: John Harrison and the Finding of Longitude*, ROYAL NAVAL MUSEUM, http://www.royalnavalmuseum.org/info_sheets_john_harrison.htm (last visited Aug. 7, 2014) [hereinafter *Biography*] ("In October 1707, the fleet of Admiral Sir Clowdisley Shovell were wrecked off the Scilly through not being able to gauge the correct longitude position of the fleet. Over two thousand men, including Shovell, were lost. This brought the subject to the fore and in July 1714, Parliament passed the Longitude Act. This convened a Board of Longitude to examine the problem and set up a £20,000 prize for the person who could invent a means of finding longitude to an accuracy of 30 miles after a six week voyage to the West Indies.").

34 *See id.*

35 *See* Roberts, *supra* note 31 ("An inability to calculate longitude had been the cause of many disasters at sea, prompting the British government to launch the Longitude prize in 1714. There would be a reward of £20,000 – several million in today's money – for the person who solved the problem.").

36 *See id.* ("While some attempted astronomical solutions, Harrison, a clockmaker by trade, was sure that an accurate timekeeper was the key to the problem."); *see also Biography*, *supra* note 33 ("One method that was examined was the finding of longitude by astronomical means.").

"Lunar Distance Method," by which sailors used the moon's position relative to the sun to determine the current time at a reference location, such as their port country.[37] Sailors could determine longitude by measuring the time at sea using the sun and comparing it to the time at port in Greenwich, UK.[38] A four-minute difference in time translates to one degree in longitude.[39]

The Lunar Distance Method required two things: an instrument for measuring the moon's position at sea, and elaborate star maps predicting the moon's future positions with high levels of precision.[40] The Astronomer Royal, a member of the Board of Longitude, hoped that the prize would encourage the development of better lunar maps.[41] These maps were extremely difficult to construct.[42]

Instead, John Harrison won the prize with his chronometer.[43] The chronometer was a clock designed to keep nearly-perfect time

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37 Richard Dunn, Lunar Distance Method, CAMBRIDGE DIGITAL LIBRARY, http://cudl.lib.cam.ac.uk/view/ES-LON-00024/1 (last visited Aug. 7, 2014).

38 *See id.*

39 *See id.*

40 *See id.* ("The lunar distance method (or lunars) was one of the means of determining longitude at sea that was made practicable in the 1760s. The method used the moon's apparent motion relative to the stars like a clock to find a reference time (e.g. the time at Greenwich). The difference between this time and local time on board the ship - determined from the sun - could be converted into a difference of longitude, one hour of time difference equating to 15 degrees of longitude. Lunars needed two things for effective shipboard use. The first was accurate tables of the Moon's future positions, for which the Observatoire de Paris and the Royal Observatory in Greenwich had been founded. . . . The second requirement was an instrument for making accurate observations from the deck of a ship. This was eventually met through the introduction of the Hadley quadrant or octant in the 1730s, and from it the sextant, which was developed during tests of Mayer's lunar tables in 1757 and 1758.").

41 *See Biography*, *supra* note 33 ("The Board consisted of the Astronomer Royal, the President of the Royal Society, First Lord of the Admiralty, Speaker of the House of Commons, the First Commissioner of the Navy Board and three professors of mathematics from Oxford and Cambridge . . . . The Astronomer Royal, Nevil Maskelyne thought that lunar tables charting lunar and star positions would be the answer to the problem. He resolutely rejected the possibility that a mechanical device could find solution to the longitude problem.").

42 *See* Dunn, *supra* note 37 ("These [lunar] motions are so complex that it was not until Tobias Mayer brought together Newtonian gravitational theory with lunar observations from Greenwich and elsewhere in the 1750s that accurate predictive tables became available. From 1767, these were made available through the Nautical Almanac, the production of which was overseen by Nevil Maskelyne.").

43 *See Harrison*, *supra* note 31.

at sea, a difficult feat given the rolling waves and salty sea air.[44] The chronometer employed two key innovations that allowed it to keep precise time during long sea voyages: it could continue marking time while it was wound; and it used heavy, fast-moving internal parts whose momentum resisted the ship's rocking.[45] The chronometer would be set to match the time at shore and would maintain this time accurately throughout the trip. Now—using only a clock—sailors could safely guide their ships.

The lesson to be learned from the Longitude Prize is simple: sometimes government can identify a problem, without knowing the best solution. Luckily, despite the Board's conviction that the winner would use astronomical methods, the Longitude Prize was technology-neutral: it was awarded to the innovator who solved the problem, regardless of his methods. But what if the Longitude Prize had been technology-specific? Instead of awarding the prize to anyone who could solve the longitude problem, it might have been awarded only to those who created lunar maps. Harrison would have kept building grandfather clocks instead of chronometers. Because the Longitude Prize was technology-neutral, it supported a better, more efficient solution.

From its historic roots, technology neutrality has become a staple of modern regulatory policy, becoming increasingly well-known and well-accepted among policymakers. Interest groups, think tanks, and academics call for greater technology neutrality.[46] The US government itself has begun to incorporate tech-neutral tenets into regulatory design. For example, since the mid-1990s, technology neutrality has become a "guiding principle" for information and communications regulation:

> In July 1997 the US Government published its Framework for Global Electronic Commerce, which stated: "rules should be

44 *See* Roberts, *supra* note 31 ("The problem was that the most faithful timekeepers of the age were pendulum clocks and you can imagine what would happen to one of those if you took it out with you on the high seas. Waves aren't at all conducive to the regular swinging of a pendulum.").

45 *See Harrison*, *supra* note 31 ("The only feature of his chronometers retained by later manufacturers was a device that keeps the clock running while it is being wound."); Roberts, *supra* note 31 ("This was the real breakthrough . . . that would make it imperturbable at sea. It beat so fast, and the balance wheel rotated so far, with such high energy, that it could not be pushed off-balance, even by a raging sea. The watch that was so hard to start was also hard to stop, hard to perturb.").

46 *E.g.*, Metcalf, *supra* note 3 (academic); NEMA, *supra* note 9 (industry group); *AEE*, *supra* note 10 (U.S. business group association).

> technology-neutral (i.e., the rules should neither require nor assume a particular technology) and forward looking (i.e., the rules should not hinder the use or development of technologies in the future)". The following year the term was used in EU legislative proposals for the first time and has been adopted in relation to most EU technology legislation ever since. Technology neutrality has also been espoused extensively by national legislators and international organisations. The desirability of technology-neutral regulation has become part of the general wisdom, and is rarely questioned.[47]

In addition, the Senate Finance Committee has suggested that technology neutrality should be a primary goal of the U.S. Tax Code in the energy and natural resources sector. On April 25, 2013, the Senate Finance Committee released a report on proposed tax reforms for infrastructure, energy, and natural resources, discussing technology neutrality as a potential reform.[48] A few months later, Chairman of the Committee, Senator Max Baucus, stated:

> Our current set of energy tax incentives is overly complex and picks winners and losers with no clear policy rationale. We need a system of energy incentives that is more predictable, rational, and technology-neutral to increase our energy security and ensure a clean and healthy environment for future generations.[49]

As tech neutrality begins to infuse our policymaking framework, it is important to carefully review its expected impact, both the benefits and the costs.

B. *What Are the Benefits of Technology Neutrality?*

Proponents of tech neutrality indicate that technology-specific incentives create economic inefficiencies because government—as opposed to the market—determines which innovations will succeed.[50] With tech-specific incentives, the government-selected

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47 Reed, *supra* note 4, at 264–65.

48 *See* SEN. FIN. COMM., *supra* note 7, at 12 (listing as the second of six "reform options" that all current tax expenditures in the energy sector be repealed and replaced with technology-neutral policies).

49 *Baucus Unveils Proposal for Energy Tax Reform,* U.S. SEN. COMM. ON FIN.: NEWSROOM (December 18, 2013), http://www.finance.senate.gov/newsroom/chairman/release/?id=3a90679c-f8d0-4cb6-b775-ca559f91ebb4.

50 *See, e.g.*, *AEE*, *supra* note 10, at 2 ("Many of today's energy tax policies were written with one sector in mind, even favoring a single technology. Such an approach distorts market signals and puts the weight of the government behind investment decisions. This approach is inefficient and imposes unnecessary risks

technologies may become "locked in," as new innovations cannot compete without a matching subsidy.[51] Innovators will be discouraged from looking for other solutions.[52] Supporters indicate that "unanticipated" or even "perverse" consequences could result from locking in technologies that are suboptimal or flawed.[53]

In comparison, technology-neutral policies would encourage the development of a range of new technologies:

> Technology-neutral incentives have the dual advantages of allowing the greatest scope for innovation and harnessing market forces to select the most economically efficient solutions.[54]

Like the chronometer, these market-driven technologies could provide better, cheaper, or more effective solutions than the technologies that government might choose.[55] This can reduce the costs of meeting policy goals.[56] In addition, it shifts the risks and rewards of research and development to the private sector.[57] Lastly, some argue that tech-neutral incentives might be simpler and easier to understand and thus more effective.[58]

C. *The AMVC: A Case Study for Tech-Specific Versus Tech-neutral*

To provide context, this Student Article will focus on

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on taxpayers.").

51 *See, e.g.*, *Metcalf*, *supra* note 3, at 8–9 (indicating that the technology-specific HEV tax is problematic because it does not provide incentives to find other ways to reduce emissions, such as improving the combustion engine); *AEE*, *supra* note 10, at 2 (arguing that favoring a specific technology distorts markets and disadvantages new innovations).

52 *See, e.g.*, *Metcalf*, *supra* note 3, at 8–9; *AEE*, *supra* note 10.

53 W. David Montgomery, *Creating a Neutral Policy Environment for Clean Technology: Principles, Benefits, and Obstacles* 2, NONPROLIFERATION POLICY EDUCATION CENTER (Dec. 1, 2008), http://www.npolicy.org/article_file/Creating_a_Neutral_Policy_Environment_for_Clean_Technology.pdf (last visited July 19, 2015).

54 *Technology-Neutral Incentives for Energy-Efficient Low Greenhouse Gas Emitting Vehicles: Hearing Before the S. Comm. on Fin.* 111th Cong. 11 (2009) (statement of Dr. David L. Greene, Visiting Scholar, Inst. for Transp. Stud., Univ. of Cal. at Davis) [hereinafter *Greene*], *available at* http://cta.ornl.gov/cta/Publications/Reports/Greene-TechneutralIncentives.pdf.

55 *See* Montgomery, *supra* note 53, at 2 (indicating that a technology-neutral approach would "[l]et investors evaluate the relative costs and let competition determine which technologies are adopted").

56 *See id.*

57 *See id.*

58 *See, e.g.*, NEMA, *supra* note 9, at 3; *AEE*, *supra* note 10.

technology neutrality as it relates to the AMVC. This Section describes the credit, explains why we need it, and sets forth the technology-neutral alternative.

1. *The Structure of the Alternative Motor Vehicle Credit*

In 2005, Congress passed the Energy Policy Act, designed to improve the nation's energy efficiency.[59] Among a number of other incentives, the Act established the AMVC, a tax credit that provides tax refunds to individuals who purchase qualifying fuel efficient vehicles.[60] The credit is technology-specific, i.e., it targets a few, particular technologies for the credit: fuel cell cars, lean burn technologies, alternative fuel vehicles, plug-in electric vehicles, and HEVs.[61]

The HEV credit is one of the most high-profile credits included in the AMVC.[62] The credit for HEVs is modest—up to a few thousand dollars—and is based on the fuel-efficiency of the car and the number of cars of that model that have been sold.[63] The credit is designed to gradually phase out for a particular model once a manufacturer sells more than sixty-thousand vehicles of that model.[64] As a result, many of the most popular brands, including the Toyota Prius and Honda Civic, quickly lost their subsidy.[65]

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59 *See* Energy Policy Act of 2005, Pub L. No. 109-58, 119 Stat. 594 (codified as amended in scattered sections of 26 U.S.C., 42 US.C.).

60 *See* 26 U.S.C. § 30B (2006).

61 *See id.* § 30B(a)(1)–(5) (listing the five types of vehicles that can qualify for the credit).

62 Google Trends indicates that "hybrid vehicle" has been searched approximately four times more often than "fuel cell vehicle" over the past ten years. "Lean burn technology" and "plug-in conversion" searches were negligible in comparison. *See* GOOGLE TRENDS EXPLORE, http://www.google.com/trends/explore#q=lean%20burn%20techology%2C%20hybrid%20vehicle%2C%20plug-in%20conversion%2C%20fuel%20cell%20vehicle&cmpt=q (last visited February 20, 2015).

63 *See* 26 U.S.C. § 30B(d) (describing the HEV credit based on gas mileage relative to a comparable, traditional vehicle); § 30B(f) (describing the phase-out based on number of vehicles sold).

64 *See id.* § 30B(f)(2).

65 *See* Noah M. Sachs, *Greening Demand: Energy Consumption and U.S. Climate Policy*, 19 DUKE ENVTL. L. & POL'Y F. 295–301 n.25 (2009) ("The Energy Policy Act of 2005 created a consumer tax credit on the first 60,000 hybrid cars sold by each automaker (with a phase-out of the credit after the 60,000 mark). Toyota hit that mark in June 2006, and Honda reached it in late 2007.").

Moreover, Congress has allowed the credit to expire altogether for three of the four qualifying technologies—all except for fuel cell vehicles.[66] Therefore, the AMVC's reach has greatly diminished. In discussing replacements for the credit, many commentators suggest switching to a technology-neutral version, as discussed in more detail in Section I.C.3. Before discussing the differences between a technology-neutral and a technology-specific version, it is helpful to review why a green vehicle tax credit was necessary in the first place.

2. *Why the AMVC Was Necessary: The Problem of Externalities*

By enacting the AMVC, Congress intervened in the natural market for automobiles. Specifically, it altered the relative price structure between HEVs and combustion engine vehicles. In traditional economic analysis, any government intervention requires justification through a failure of the market. Here, the government had a strong justification for its choice to intervene: automobile emissions—along with energy security issues—create a significant "externality" problem in the consumer car market.

An externality is a cost associated with a good that is imposed on third parties: neither the buyer nor the seller pays it.[67] This deviates from the ideal economic case in a perfectly competitive market.[68] In that case, the price of a good on the market should be equal to the total cost of producing it.[69] If this is true, then all purchases will be economically efficient; they will increase—or, at least, not decrease—the total value to society, known as the "economic surplus."[70]

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66 *See* IRS, ALTERNATIVE MOTOR VEHICLE CREDIT, http://www.irs.gov/uac/Alternative-Motor-Vehicle-Credit-1 (last visited Jan. 7, 2015).

67 More generally, the definition of an externality is any time a cost or benefit is imposed on an actor by third parties outside of his control. *See* James M. Buchanan and Wm. Craig Stubblebine, *Externality*, 29 ECONOMICA 371, 372 (1962). However, this Article focuses on externalized costs (rather than benefits) in the context of a buyer-seller relationship.

68 The perfectly competitive market requires making a number of assumptions about the market goods and actors, such as perfect information, perfect rationality, no transaction costs, etc. *See, e.g.*, Competitive Market Model Assumptions, ECONPORT, http://www.econport.org/content/handbook/industrialorg/Competitive/Assumptions.html. (last visited Jun. 29, 2015). Most relevant here, it includes the assumption that there are no externalities. *See id.*

69 *See generally* PAUL KRUGMAN & ROBIN WELLS, MICROECONOMICS 453–76 (2012) (defining externalities and explaining their basic effects and appropriate interventions).

70 *Id.*

To see why, consider more closely the meaning of a consumer's decision to purchase. If a buyer purchases a good, it means she is willing to pay at least the price of that good. This means that, to her, the good is worth more than—or equal to—the price. For example, if an apple costs one dollar in the store, and John buys the apple, he must value it at one dollar or more.

As a result, whenever the price equals the total cost of production—as in the ideal case—buyers will only purchase the apple if its value to them meet or exceeds its cost of production. For example, if the apple costs one dollar to grow, ship, and sell, then its price on the market will be one dollar. John will only buy the apple if his value for the apple is greater than or equal to the one dollar cost of production. In short, whenever price equals cost, all buyers value the good at an amount greater than or equal to production cost. This means that the purchase is net positive: it creates more value than it destroys.[71] In economic terms, it increases the economic surplus.

On the other hand, in the case of an externality, the actors making the pricing and purchasing decisions are not paying the full cost.[72] As a result, the externalized portion of the cost is not reflected in the ticket price.[73] This can have negative consequences. Specifically, some consumers will value the good at an amount higher than the ticket price, but lower than the true cost to society, i.e., the full costs of production to the seller, plus any positive or negative externalities. These consumers' purchases are net social losses: the cost to society is higher than the value to the buyers. However, since the ticket price is lower than the consumers' value, they will still purchase the good. For example, suppose the apple costs the apple company one dollar to produce. John values it at one dollar and five cents, so he purchases it, but the environmental harms from the farm's fertilizers impose an aggregate cost of ten cents on its neighbors. The total cost of the apple is $1.00 plus $0.10, or $1.10. John values it at $1.05—five cents less than $1.10 cost to society—so the total value in the society drops by a nickel.[74] These purchases are undesirable: they

71 Note that, if the buyer's value for the product is exactly equal to the price, then it would have a net zero outcome, but it will never have a negative outcome.

72 *See id.*

73 *See id.*

74 Note that if *either* the producer or the purchaser pays the costs—as long as one of the parties to the transaction internalizes each cost—the outcome will still be efficient. For example, if the apple company had to pay the farm's neighbors

reduce the total welfare. Consumers will buy an inefficiently large volume of this good.[75]

In the case of motor vehicles, the two most significant externalities are damage to the environment from tailpipe emissions and dependence on foreign oil.[76] In the absence of regulation, these harms are imposed on third parties—the former, globally, and the latter, nationally—rather than borne by the buyer or seller. To elaborate, when potential car buyers make purchase decisions, the primary cost they face is the car's ticket price. However, combustion engine automobiles will also emit greenhouse gases that drive climate change, resulting in a cost to society known as the Social Cost of Carbon (SCC).[77] Likewise, drivers must purchase gasoline to use their traditional cars, and demand for this gasoline makes the United States vulnerable to changes in foreign oil supply and constrains U.S. foreign policy.[78] These costs are borne by society, not by the driver as an individual. As a result, buyers will not consider, or "internalize," the full cost of their traditional car purchases. This results in a demand for traditional combustion engine vehicles that is above the socially efficient level.

From an economic perspective, market failures, including

for the ten-cent cost of the fertilizer, then the apple company would set the price at ten cents higher, or $1.10. John would no longer value the apple at more than the price, and he would not make the inefficient purchase. Alternatively, suppose the cost of the apple fertilizer was not on the farm's neighbors but on John himself. If John eats the fertilized apple, there is a very small chance the fertilizer will make him sick. John values this as a ten-cent cost. Now, John's net value for the apple will be $1.05 minus $0.10 or $0.95. Since 95 cents is less than the price of the apple, John will no longer buy the apple.

75 In other words, either each purchaser will buy more of the good than is efficient, or some people will purchase even though it is inefficient for them to purchase at all, or some combination of the two.

76 *See Metcalf*, *supra* note 3, at 3 ("I would argue that two [externalities of energy use] dominate the agenda. First is the concern with global climate change arising from increasing concentrations of greenhouse gases in the atmosphere . . . . A second concern is our heavy reliance on petroleum products and the dominance of this fuel in the transportation sector.").

77 *See generally* David Pearce, *The Social Cost of Carbon and Its Policy Implications*, 19 OXFORD REV. ECON. POL'Y 362 (2003).

78 *See Metcalf*, *supra* note 3, at 3 ("Our reliance on petroleum makes us vulnerable to economic dislocations from sharply rising oil prices or supply disruptions . . . . Many have argued that our heavy reliance on oil constrains our foreign policy, drives up our military costs, and makes us vulnerable to macroeconomic shocks when oil prices rise as they did over the past few years.").

externalized costs, justify government intervention.[79] In order to counteract the market failure here, the intervention must decrease the demand for traditional, dirty vehicles. One method for decreasing the demand for traditional cars would be to impose a tax on them.[80] A tax on dirty vehicle purchases equal to the SCC[81] of the cars' tailpipe emissions would successfully internalize the externality.[82] This would reduce demand for traditional vehicles to the socially efficient levels. Every buyer would foot the full bill. Another way of decreasing the demand for a product is to increase the demand for a substitute product.[83] This is the tactic used in the AMVC.[84] Rather than directly taxing the purchase of dirty vehicles, the AMVC attempts to encourage consumers to switch to a substitute product: green vehicles.[85] HEVs and traditional vehicles are substitutes because buyers are unlikely to purchase a dirty car if they have already bought a green car, and vice versa.[86]

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79 *See id.* at 2 ("Economic theory provides clear prescriptions for situations where interventions through the tax code can improve social welfare. Externalities provide the most relevant rationale for the energy sector. If the production or consumption of energy has as a by-product the creation of an externality (e.g. pollution) then social welfare can be improved through government intervention.").

80 *See Metcalf*, *supra* note 3, at 2 ("One way to do this is by taxing the externality. Thus a tax on the sulfur content of fossil fuels, for example, would be an efficient response to acid rain damages arising from fossil fuel consumption for electricity generation."). *See generally* ARTHUR C. PIGOU, THE ECONOMICS OF WELFARE (1938).

81 As mentioned above, there are non-environmental social costs to tailpipe emissions that might not be included in the environmentally-focused SCC calculations. For simplicity, this Article will generally refer to the SCC as including all social costs of carbon.

82 *See Metcalf*, *supra* note 3, at 2–3 (indicating that the proper tax amount is equal to the cost of the externality).

83 *See id.* at 3 ("Rather than taxing activities that create negative externalities, we can provide subsidies to activities that are substitutes for externality-generating activities. Put simply, if fuel X generates pollution damages while fuel Y does not, we can raise the price of fuel X relative to fuel Y to reflect the social damages from burning fuel X or we can reduce the price of fuel Y. Either approach encourages firms to use less of fuel X and more of fuel Y.").

84 It is also the tactic generally taken in U.S. energy policy, which tends to subsidize energy efficient alternatives, rather than tax fossil-fuels. *See id.*

85 *See id.*

86 *See* David Diamond, *The Impact of Government Incentives for Hybrid-Electric Vehicles: Evidence from US States,* 37 ENERGY POL'Y 972, 976 (2009) ("Honda Civic Hybrid, Toyota Prius and Ford Escape . . . represented the top selling hybrid sedans and the top selling hybrid SUV (through 2006) and . . . each of these HEVs is in the median price range for their vehicle class (approximately $20,000–25,000), so they represent a reasonable substitute to

In order to increase the demand for HEVs, the tax credit effectively decreases their price by refunding purchasers. This should increase the demand for HEVs, leading to a decreased demand for traditional vehicles.

3. *The Tech-Neutral Alternative*

As mentioned above, some commentators have suggested replacing the AMVC with a tech-neutral version, expanding the credit to any technology rather than directing it at specific types.[87] A Senate Finance Committee Report suggested adopting the "Tax Credit for Fuel Efficient Vehicles" proposed in Senate Bill 1620.[88] The Tax Credit for Fuel Efficient Vehicles would be awarded to any vehicle with better fuel efficiency than the average vehicle in its class, as determined by the corporate average fuel economy (CAFE) standard.[89] The credit amount would be equal to $1,000 for each hundredth of a gallon-per-mile (note that this is GPM, not MPG) by which the fuel-efficient vehicle's fuel economy rating exceeded the CAFE standard.[90]

The Tax Credit for Fuel Efficient Vehicles is technology-neutral: the credit is available regardless of what technology the car uses. Like the AMVC, this new credit would mitigate the market failure caused by fuel externalities. But, unlike the AMVC, it would not promote any particular technology. As a result, it would provide more flexibility to the automobile industry to develop new technologies, possibly ones that surpass any technology policymakers could have anticipated.[91] If the government "picks winners" by backing HEVs, it could discourage

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conventional gasoline sedans for most consumers purchasing new cars."); *Metcalf*, *supra* note 3, at 3 (indicating that subsidizing alternative forms of fuel will reduce the amount of fossil fuel used because the two are substitutes).

87 *See* S. COMM. ON FIN., *supra* note 7, at 11 ("Some believe that it would be more efficient to structure these incentives, to the extent they are retained, on a technology-neutral basis. They argue that such an approach would be more effective at accommodating and encouraging technological advances and would avoid picking winners and losers among competing technologies.").

88 *Id.* at 13 (citing S. 1620, 111th Cong. §1 (2009), *available at* http://www.gpo.gov/fdsys/pkg/BILLS-111s1620is/pdf/BILLS-111s1620is.pdf).

89 *Id.*

90 S. 1620, 111th Cong. §1, at 3–4 (2009).

91 *See Greene*, *supra* note 54, at 5 ("The motor vehicle industry responded [to California's technology-neutral vehicle emissions standards] with unanticipated technologies, such as the three-way catalyst, multi-point fuel injection and computerized control of combustion that reduced emissions by orders of magnitude.").

innovation among researchers and producers.[92] The Tax Credit for Fuel Efficient Vehicles would give flexibility to innovators, and could ultimately promote better technologies, as discussed in Section I.B.

II. The Diffusion of Innovations and Consumer Adoption

Section I reviewed the expected benefits of technology-neutral policies, with a particular focus on the AMVC. The heart of tech neutrality's appeal is that it encourages industry to invest time and money into developing a range of new products, and it avoids lock-in for second-best technologies.[93] The benefits of technology neutrality tend to focus on research and development incentives within the industry.

This Student Article does not challenge these benefits. Instead, the goal is to recognize that technology neutrality, like any other policy, also has costs and limits. These costs have rarely been examined.[94] This Article seeks to bring more attention to the potential drawbacks of technology-neutral policies.

To examine the costs of technology neutrality, this Article will switch focus from the industry to the end user. The behavior of end-users under a technology-neutral policy is at the unfortunate intersection of two research gaps: just as discussions of technology neutrality have often overlooked its *costs*, discussions of innovation policy also overlook the importance of the *end user*.[95] Therefore, it is not surprising that the costs of technology neutrality on end-user behavior have been under-researched.

However, adoption is key to the efficacy of any green technology—if it never reaches the consumer, it can never have an impact.[96] In light of the import of adoption, this Article seeks to fill

92 *See* S. COMM. ON FIN., *supra* note 7, at 11.

93 *E.g.*, Montgomery, *supra* note 53, at 2.

94 *See* Reed, *supra* note 4, at 265 ("The desirability of technology-neutral regulation has become part of the general wisdom, and is rarely questioned.").

95 *See* Spencer & Vadari, *supra* note 14, at 50 (2009) ("Typically overlooked during discussions of potential smart-grid benefits, is how presumed adoption rates will be achieved and sustained."). Even authors who admit the importance of diffusion still focus predominantly on issues of innovation. *E.g.*, Wesley A. Magat, *The Effects of Environmental Regulation on Innovation*, 43 LAW & CONTEMP. PROBS. 4, 5 (1979) *available at* http://scholarship.law.duke.edu/lcp/vol43/iss1/2 ("Although the full impact of technological advance will not occur until it has moved through the diffusion stage, we will have less to say about this latter stage.")

96 *See* Derzko, *supra* note 15, at 40 ("[E]nvironmental technologies must

the gap in the policy literature, using Innovation Diffusion theories, which span fields as diverse as economics, sociology, marketing, and psychology.[97] Drawing from these fields, this Article examines the factors that promote adoption. Making policy in light of these factors can produce tactics that will make consumers more likely to adopt a desired product or behavior change. With that goal in mind, this Section introduces the basic concepts of innovation diffusion and consumer behavior. Subsequently, Section III will use insights from innovation diffusion theory to evaluate the costs of technology neutrality for the AMVC.

A. *Consumer Adoption Decisions and Bounded Rationality*

At this point, it is worth clarifying that the term "innovation," as popularly used, is semantically misleading. There are actually three stages that are associated with innovation: invention, innovation, and diffusion.[98] "Invention" is the initial creation or discovery of a new technology;[99] "innovation" involves developing this technology from a prototype to a marketable commercial product;[100] and "diffusion" is the ultimate adoption of this technology.[101] While invention and innovation relate to industry choices to engage in research and development, diffusion relates to end users.

This Section focuses on the final stage, the diffusion of

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pass successfully into the diffusion stage if the innovation is to become widely used and thus truly useful for society.").

97 *E.g.*, Thomas S. Robertson & Hubert Gatignon, *Competitive Effects on Technology Diffusion*, J. MKTG., July 1986, at 1 (marketing); ROGERS, *supra* note 17 (sociology); PAUL STONEMAN, THE ECONOMICS OF TECHNOLOGICAL DIFFUSION 29–52 (2002) (economics); Mieneke W. Weenig & Cees J. Midden, *Communication Network Influences on Information Diffusion and Persuasion*, 61 J. PERSONALITY & SOC. PSYCHOL.734 (1991) (psychology).

98 Kurt A. Strasser, *Preventing Pollution*, 8 FORDHAM ENVTL. L.R. 1, 1, 16 n.57 (1996) ("The term innovation presents a semantic difficulty here. In the economic analysis of technological change, three distinct stages are separated for purposes of analysis.").

99 *Id.* ("Invention, the first stage, involves creating new scientific or technological knowledge.")

100 *Id.* ("The second stage, conventionally labeled innovation, is the development of this invention through the prototype stage until a commercially viable product or technology results.").

101 *Id.* ("The third stage, diffusion, is the spread of this innovation effort."); Derzko, *supra* note 15, at 40 ("The final stage in the three-step cycle of new technology development, diffusion, is the stage during which the newly developed technology is disseminated throughout the marketplace.").

innovations. In particular, the focus of this Student Article is diffusion of consumer durables. Unlike the chronometer, whose target audience was professionals in the nautical field, HEVs and other green consumer goods must be adopted by relatively unsophisticated end users. People in widely varying circumstances—with different levels of expertise, interest, and resources—must decide whether or not to use these innovations. And in order for the innovation to have an impact, many of these people must adopt.

The distinction between consumers and experts is important. Consumers are less likely than sophisticated industry experts to behave like homo economicus—i.e., the perfectly rational human of neoclassical economic theory.[102] As a result, it makes sense to focus on behavioral impacts with respect to the AMVC.

To clarify, this Article has so far introduced economic concepts based on a purely rational framework. Early economic conceptions of human decision-making assumed that humans were perfectly rational, with "demonic powers of reason, boundless knowledge, and all of eternity with which to make decisions."[103] However, empirical results support a more plausible understanding of the human mind: individuals' decisions are only boundedly rational.[104] In other words, humans are limited in their ability to analyze the relevant facts and identify the best choice.[105] This Article will now move from the purely rational to the boundedly-rational understanding of decision-making. This means that the core assumptions of classical, rational economics are relaxed, allowing for a more behavioral viewpoint.

Regarding HEVs, other authors have already lamented the difference between human *qua* consumer and homo economicus.[106] For many consumers, the rational choice is to adopt HEVs; even without any government intervention, purchasing an

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102 *See, e.g.*, Richard H. Thaler, *From Homo Economicus to Homo Sapiens*, 14 J. ECON. PERSP. 133 (2000).

103 *See* GIGERENZER & TODD, *supra* note 16, at 5.

104 *See* Christine Jolls, Cass R. Sunstein & Richard Thaler, *A Behavioral Approach to Law and Economics*, 50 STAN. L. REV. 1471, 1476–81 (1998) (reviewing a number of empirical studies that provide support for bounded rationality, bounded will-power, and bounded self-interest).

105 *See id.* at 1477 ("Bounded rationality, an idea first introduced by Herbert Simon, refers to the obvious fact that human cognitive abilities are not infinite.").

106 *See*, *e.g.*, *Greene*, *supra* note 54, at 2–3 (indicating that behavioral issues beyond traditional market failures impact consumer choices regarding HEVs).

HEV can be less costly than a traditional vehicle.[107] Specifically, because of fuel savings, buying an HEV will save some owners more money in avoided gasoline expenses than it costs them in an increased ticket price.[108] Still, the vast majority of consumers do not purchase HEVs.[109] In fact, HEVs are just one of many economically efficient green technologies that homo economicus would adopt, but homo sapiens often does not.[110] This means that the cost externality is not the only problem. Some consumers are not actually making a rational choice in the face of a flawed cost structure. Instead, they are making an irrational choice.

Environmental engineer Dr. David Greene testified before the Senate Finance Committee that consumers' hesitance to buy HEVs despite potential financial gains can be explained by two behavioral limits on the purely rational model: uncertainty and loss-aversion.[111]

> When the inherent loss-aversion of typical consumers is taken into account, technologies that are cost-effective in terms of their expected payoff appear to be too risky . . . . The implications of uncertainty and loss-aversion match up almost exactly with the views expressed . . . by auto manufacturers, who stated that consumers were willing to pay only for

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107 *See id.* (indicating that, in 2009, some HEV models would save consumers as much as $405 in the long run); *See* Robert Duffer, *Do Hybrid Cars Save Money?*, CHICAGO TRIBUNE (June 12, 2014), http://articles.chicagotribune.com/2014-06-12/classified/chi-do-hybrid-cars-save-money-20140612_1_lincoln-mkz-hybrid-lexus-ct-prius (indicating that, in 2014, some HEVs can save consumers thousands of dollars, but that savings—if there are any—ultimately depend on the car's model and user's circumstances).

108 *See* Duffer, *supra* note 107.

109 According to the Department of Energy, fewer than 500,000 HEVs were sold in 2013. *See* U.S. DEP'T OF ENERGY, ALTERNATIVE FUELS DATA CTR., U.S. HYBRID ELECTRIC VEHICLE SALES BY MODEL [hereinafter *HEV Sales*], *available at* www.afdc.energy.gov/data/10301. In comparison, there were 15.6 million total new passenger cars and trucks sold in the United States in 2013. *See* Angelo Young, *US New Auto Sales 2013: Year Closes As Expected, But December Disappoints; Ford Sales Topped 10% In 2013 While Chrysler, Nissan Hit 9%*, INT'L BUSINESS TIMES (Jan. 3, 2013), http://www.ibtimes.com/us-new-auto-sales-2013-year-closes-expected-december-disappoints-ford-sales-topped-10-2013-while.

110 *See* MCKINSEY& CO., IMPACT OF THE FINANCIAL CRISIS ON CARBON ECONOMICS: VERSION 2.1 OF THE GLOBAL GREENHOUSE GAS ABATEMENT COST CURVE 8 (2010) [hereinafter COST CURVE], *available at* http://www.mckinsey.com/client_service/sustainability/latest_thinking/greenhouse_gas_abatement_cost_curves (listing a number of green alternatives to traditional technologies that would provide cost savings).

111 *See Greene*, *supra* note 54, at 3–4.

> technologies which paid back their cost in 2 to 4 years. If one assumes that consumers value future fuel savings using a simple 3-year payback rule, future fuel savings are undervalued by a factor of 2, or more.[112]

Because consumers undervalue future fuel savings, there are some who fail to realize that they would save money in the long run by purchasing an HEV. According to Greene, these consumers—though not all consumers[113]—should purchase HEVs, but they do not. They fail to make the economically efficient choice.

Greene continues on to suggest that "[t]he phenomenon of uncertainty and loss-aversion in the market for fuel economy does not constitute a market failure in the usual sense."[114] In other words, starting from the classical assumption that consumers are rational, no market failure exists that can explain this behavior. Loss-aversion does not exist in a purely rational model. In order to explain the market failure here, we have to assume that consumer decision-making is not perfectly rational. It is subject to market failures that are caused by irrationality. In that case, purely rational, cost-focused interventions may overlook important considerations about adoption choices.

Therefore, it is useful to take a more behavioral approach. Greene recognizes uncertainty and loss-aversion as two behavioral limits on consumer choices regarding HEVs.[115] This Article focuses on an additional behavioral limit: the human tendency to rely on "heuristics" to compensate for our "bounded rationality."[116] One way to characterize boundedly rational decision-making is that it is accomplished through "heuristics."[117] A heuristic is a method that individuals use to make reasonably efficient decisions, while investing relatively small amounts of time and resources.[118] In short, heuristics represent how humans make choices with limited time, information, and brain power.

Many innovation diffusion researchers have developed

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112 *See Greene*, *supra* note 54, at 3.

113 *See* Duffer, *supra* note 107 (indicating that whether an HEV would save money for a consumer "depends on how much you drive, how you drive and how long you own your car.").

114 *Greene*, *supra* note 54, at 4.

115 *See id.*

116 *See* Jolls, *supra* note 104, at 1477.

117 GIGERENZER & TODD, *supra* note 16, at 15–16 (providing a theory of "fast and frugal" heuristics in order to understand bounded rationality as "the way that real people make the majority of their inferences and decisions.").

118 *See id.*

heuristic-based models of consumers adoption choices—models that assume individuals engage in something less than the perfect rational decision-making process.[119] Although it is beyond the scope of this Article to delve into the details of all of the potential heuristics, it is possible to draw some overarching conclusions about the variables that consumers' adoption heuristics are likely to be based on. The following Subsection introduces the work of Everett M. Rogers, which can provide insights into the elements of decision-making heuristics that consumers use. His work indicates that innovation diffusion heuristics are often based significantly on peer behaviors and information passed along social networks.[120]

B. *Everett Rogers's Theory of Innovation Diffusion*

Everett M. Rogers provides the seminal work on the diffusion of innovations,[121] which continues to be widely cited and accepted

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119 Not all of these models explicitly use the term "heuristics." The point is that they assume individuals make decisions based on something other than perfect information, perfect computational ability, and perfect rationality. For a discussion of the many models of innovation diffusion, see *infra* Section II.C.

120 *See, e.g.*, Nina Schwarz & Andreas Ernst, *Agent-Based Modeling of the Diffusion of Environmental Innovations — An Empirical Approach*, 76 TECH. FORECASTING & SOC. CHANGE 497, 504 (2009) ("The concept of bounded rationality is represented by using a heuristic. Here, the so-called 'take-the-best' heuristic was chosen: A set of evaluation criteria (here: innovation characteristics and social norm) is sorted, starting with the most important criterion. All options (here: technologies within a category) are evaluated. If there is a clear solution favoring one option, this option is chosen, else the next criterion is evaluated. If the take-the-best-heuristic does not lead to a distinct solution, favoring exactly one option, agents imitate the behavior of their peers.").

121 Jon Kleinberg describes the theory of innovation diffusion and cites Rogers as among the original researchers on the topic:

> The process by which new ideas and new behaviors spread through a population has long been a fundamental question in the social sciences. New religious beliefs or political movements; shifts in society that lead to greater tolerance or greater polarization; the adoption of new technological, medical, or agricultural innovations; the sudden success of a new product; the rise to prominence of a celebrity or political candidate; the emergence of bubbles in financial markets and their subsequent implosion — these phenomena all share some important qualitative properties. They tend to begin on a small scale with a few "early adopters"; more and more people begin to adopt them as they observe their friends, neighbors, or colleagues doing so; and the resulting new behaviors may eventually spread through the population contagiously, from person to person, with the dynamics of an epidemic. People have long been aware of such processes at an anecdotal level; the systematic study of them developed, in the middle of the 20th century, into an area of sociology known as the diffusion of

today. In fact, "[c]onsumer behavior researchers have adopted the paradigm of Rogers without much qualification."[122]

Rogers's model is complex, but can be reduced to a few essential concepts. Rogers defines an innovation as "an idea, practice, or object that is perceived as new."[123] Adoption occurs as individuals learn about the existence and characteristics of an innovation from one another, and based on this information, decide whether the innovation is preferable to the existing, mature technology or process: "The essence of the diffusion process is the human interaction in which one person communicates a new idea to another person."[124]

According to Rogers, after an individual becomes aware of an innovation, he must decide whether or not to try it.[125] This is called the "evaluation stage."[126] At this point, consumers need more information about the product.

> The innovation carries a subjective risk to the individual. He is unsure of its results . . . . Information and advice from peers is likely to be sought at this point. Mass communications transmit messages that are too general to provide reinforcement to the individual at the evaluation stage.[127]

Rogers identified the same flaws in the adoption of innovations in general that Greene blamed for consumers' failure to adopt HEVs in particular: risk and imperfect information.[128] Many other researchers cite these two failures as the barriers to HEV adoption.[129]

> innovations. The initial research on this topic was empirical (see e.g. . . . [Rogers])

Jon Kleinberg, *Cascading Behavior in Networks: Algorithmic and Economic Issues*, *in* ALGORITHMIC GAME THEORY 613, 613 (Noam Nisan et al., eds., 2007), *available at* http://www-cgi.cs.cmu.edu/afs/cs.cmu.edu/Web/People/sandholm/cs15-892F13/algorithmic-game-theory.pdf #page=634.

122 Thomas S. Robertson & Hubert Gatignon, *Competitive Effects on Technology Diffusion*, J. MKTG., July 1986, at 1 (internal citation omitted).

123 ROGERS, *supra* note 17, at 12.

124 *Id. at 17.*

125 *See id.* at 81–83.

126 O.N. Mohamedali, *Practical Agriculturists, Literacy and Agricultural Information in East Africa*, 27 LIBRI 341, 346 (1977).

127 *Id.* at 346–47.

128 *See generally* Rogers, *supra* note 17.

129 *See, e.g.*, Diamond, *supra* note 86, at 972 (citing Adam B. Jaffe & Robert N. Stavins, *The Energy Efficiency Gap: What Does It Mean?* 22 ENERGY POL'Y 804 (1994); Paul Stoneman & Paul Diederen, *Technology Diffusion and Public Policy*, 104 THE ECON. J. 918 (1994); Linda Argote & Dennis Epple, *Learning Curves in Manufacturing*, 247 SCIENCE 920 (1990)) ("[H]ybrids also face

Rogers's claim that lack of information prevents consumers from making efficient choices is not uncommon.[130] Providing consumers with information can combat this.[131] However, Rogers points out something more: the source of the information is also important. Specifically, people are more likely to rely on information from their peers than on mass media when evaluating an innovation.[132] This distinction has potentially far-reaching implications. Market interventions that focus solely on increasing total information, while ignoring the type of information, may not be fully effective. In short, to combat the uncertainty and loss-aversion that Greene identifies,[133] it may be necessary to encourage information-sharing among peers, rather than distributing it from the government or mass media.

C. *Evidence of Social Network Influence in Green Innovations*

Subsequent innovation diffusion models validate Rogers's findings. They continue to emphasize personal communication in adoption decisions.[134] The importance of face-to-face information

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barriers to adoption that are common to any new technology, such as lack of knowledge by potential adopters, low consumer risk tolerance, and high initial production costs . . . .").

130 Many researchers cite a lack of information as key to consumers' inability to make efficient choices. *See, e.g.*, Shmuel I. Becher, *Asymmetric Information in Consumer Contracts: The Challenge That Is Yet to Be Met*, 45 AM. BUS. L. J. 723, 734 (2008) ("[I]nformation inequalities belie the maxim that promisees (i.e., consumers) are the best judges of their own utility. Where imperfect information exists, the ability of parties to maximize utility via open market transactions will inevitably decrease."); Silber, *supra* note 16, at 863 ("As a result of the misinformation they receive all the time—and useful information they receive only too little and too late—many consumers are ill-equipped to pursue their own best financial interests.").

131 *See* Joost M. E. Pennings et al., *A Note on Modeling Consumer Reactions to a Crisis: The Case of the Mad Cow Disease*, 19 INT'L J. OF RES. MKTG. 91, 98–99 (2002) (suggesting that, where consumer choice is driven by risk perceptions, information dissemination by government, industry, and media is necessary to correct misperception, based on a study of consumer beef choices during a mad cow scare).

132 *Compare id.* ("[R]isk perceptions . . . drive consumer behavior, suggesting the need for tough measures, but also for extensive and responsible dissemination of accurate information by government, industry and media."), *with* ROGERS, *supra* note 17, at 175 ("The individual wants to know whether his or her thinking is on the right track in the opinion of peers. Mass media messages are too general to provide the specific kind of reinforcement that the individual needs to confirm his or her initial beliefs about the innovation.").

133 *See supra* Section II.A.

134 *E.g.*, PAUL STONEMAN, THE ECONOMICS OF TECHNOLOGICAL DIFFUSION 29–52 (2002) (reviewing various models in the economic literature, many of

has long been confirmed by empirical studies.[135] This Student Article will use the term "social network influence" to refer to this impact of peer-based information on innovation decision-making.

Moreover, many studies have found that social network influences are particularly strong in the context of green innovations. One of the earliest examples comes from Rogers himself. Rogers indicates that solar panel water-heating was adopted in clusters in California neighborhoods.[136] This clustering effect was subsequently attributed to the tendency for neighbors to "observe and discuss the costs and benefits of installing this technology."[137] In other words, solar-panel users passed information along their social networks to neighbors, who in turn used this information to decide to adopt solar panels.

A more recent example comes from a study of energy conservation techniques in California.[138] In 2003 and 2004, researchers conducted a survey, asking respondents how often they

which rely on communication of information on social networks); JOE TIDD, GAINING MOMENTUM: MANAGING THE DIFFUSION OF INNOVATIONS 13–26 (2010) (reviewing models of diffusion in the marketing literature with an emphasis on communication); Gershon Feder, Richard E. Just & David Zilberman, *Adoption of Agricultural Innovations in Developing Countries: A Survey*, 33 ECON. DEVELOPMENT & CULTURAL CHANGE 255, 266 (1985) (citing ROGERS, *supra* note 17; Edwin Mansfield, *Technical Change and the Rate of Imitation*, 29 ECONOMETRICA 741 (1961)) ("Many of these studies stress the role of communication (Rogers 1969), as done in Mansfield's (1961) seminal paper, which derives analytically an S-shaped diffusion path assuming that the driving force of the diffusion process is imitation."); Peresa, Muller & Mahajane, *supra* note 20, at 92 ("Innovation diffusion is the process of the market penetration of new products and services that is driven by social influences, which include all interdependencies among consumers that affect various market players with or without their explicit knowledge."); Redmond, *supra* note 20, at 172 ("Word-of-mouth recommendations are known to exercise a powerful influence on choice outcomes when the purchaser has little personal knowledge or expertise in the area of decision-making.").

135 *See, e.g.*, Herbert Menzel & Elihu Katz, *Social Relations and Innovation in the Medical Profession: The Epidemiology of a New Drug*, 19 PUB. OP. Q. 337, 337 (1955) ("A study of drug adoptions by physicians allowed the introduction of socio-metric techniques into a field survey of decision-making . . . . This pilot study confirms the role played by face-to-face contacts in mediating influences from the outside world in a case of decision-making among professional experts.").

136 *See* EVERETT M. ROGERS, DIFFUSION OF INNOVATIONS 303–04 (3rd ed. 1983).

137 Robin Roy et al., *People Centered Eco-Design: Consumer Adoption of Low and Zero Carbon Products and Systems*, *in* GOVERNING TECH. FOR SUSTAINABILITY 41, 44 (Joseph Murphy ed., 2007).

138 *See* Jessica M. Nolan et al., *Normative Social Influence Is Underdetected*, 34 PERS. SOC. PSYCHOL. BULL. 913 (2008).

tried to conserve energy.[139] They also asked respondents to self-report their own motivations for energy conservation and to provide estimates of the proportion of their neighbors and fellow city and state residents who also tried to conserve energy.[140] The study found that, regardless of respondents' claims about their own motivations, the strongest predictor of respondents' conservation choices was their estimation of the number of their peers that conserved energy.[141] Estimates of peers' behavior accounted for 21% of the variance.[142] A follow up experiment revealed that "the strongest correlate of conservation behavior was the belief that other people were doing it."[143]

A study by Wander Jager on the diffusion of photovoltaic (PV) systems, which relied heavily on Rogers's model, provides a slightly different perspective.[144] In constructing his experiment, Jager acknowledged the importance of sharing information over social networks:

> Network effects may be critical in the diffusion process, as not only information on the innovation is communicated through social networks, but also social norms related to social needs [citation omitted]. Within the context of home insulation measurements, Weenig and Midden (1991) report that information diffusion and final adoption were related to the social ties people had, thus signifying the importance of

139 *See id.* at 915 (indicating that the researchers conducted phone interviews with 810 California residents).

140 *See id.* at 915–16.

141 *Id.* at 917.

142 *Id.*

143 *Id.* at 917. *See also* Charlie Wilson, *Social Norms and Policies to Promote Energy Efficiency in the Home*, 38 ENVTL. L. REP. NEWS & ANALYSIS 10882, 10885 (2008) (citing Nolan, *supra* note 138) (summarizing the Nolan research project). In Nolan's follow-up study, researchers directly measured 981 participants' energy conservation practices by reading their home energy meters. *See* Nolan, *supra* note 138, at 918. The experiment involved placing door-hangers on participants' front doors, promoting a number of energy-conserving habits: shorter showers, turning off lights and air conditioning, and substituting fans for air conditioners. *See id.* The door hangers used one of five messaging tactics to persuade the participants to adopt these habits: "social responsibility," "self-interest," "environmentally focused," "information only," or "normative." The normative condition informed participants of the percentage of their neighbors who were conserving energy. Although those with the normative message tactic reported that the messaging had the lowest impact on them, it actually produced the highest reduction in energy. *See id.* at 918–20.

144 *See* Wander Jager, *Stimulating the Diffusion of Photovoltaic Systems: A Behavioral Perspective*, 34 ENERGY POL'Y 1935 (2006).

network effects.[145]

Jager's survey relied on self-reporting by adopters of a PV system.[146] The study found that, while social motives were relevant to respondents, they were not the strongest motivation.[147] However, Jager found that "the more other PV owners a person knows, the stronger these social motives become."[148] This may indicate that adopters prefer to rely on social information when they have access to it. In addition, Jager found that "social motives are more important to people investing less cognitive effort in the initial phase of the decision process."[149] He indicates that these results are consistent with Rogers's prediction that later adopters will give more weight to their peers' behaviors.[150] Moreover, since the Jager study was a self-reporting survey, according to Nolan, peers' choices are likely to be even more influential than reported.[151]

III. THE COSTS AND LIMITS OF TECHNOLOGY NEUTRALITY

In light of the social network influences that occur during the diffusion of innovations, this Section will point out two concerns that arise from a technology-neutral version of a tax credit, as compared to a technology-specific version. Section III.A will discuss issues that arise because technology-neutral policies will result in multiple market entrants, thereby increasing the risk of "Standard Wars." Section III.B will explain why "visibility" matters in the context of innovation diffusion and will indicate that a technology-neutral policy will be less able to promote visibility.

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145 *Id.* at 1937 (citing Sebastiano Delre et al., Percolation and Innovation Diffusion Models Compared: Do Network Structures and Social Preferences Matter?, Paper presented at the M2M2 workshop of the ESSA2 conference, Valladolid, Spain (2004); Mieneke W. Weenig & Cees J. Midden, *Communication Network Influences on Information Diffusion and Persuasion*, 61 J. Personality & Soc. Psychol.734–742 (1991)).

146 *See id.* at 1938 (indicating that a questionnaire was used to elicit responses).

147 *See id.* at 1939.

148 *See id.* at 1941.

149 *Id.* at 1942.

150 *See id.*; ROGERS, *supra* note 17, at 211–12.

151 The Nolan study indicates that people claim to be motivated by other factors—like social responsibility and environmentalism—while, in fact, the strongest determinant is their belief about others' choices. Nolan, *supra* note 138. As a result, social influence is "underdetected," as the title indicates, because it tends not to be self-reported. Therefore, since Jager relies on self-reporting, it is likely that social influence is higher than Jager's study detected.

A. *Threshold Models and The Impact of Diffusing Multiple Entrants*

Because of social network influence and the importance of peer-based information, adoption decisions become self-reinforcing: each new adopter encourages still more adopters.[152] Rogers explains that there are

> cumulatively increasing influences upon an individual to adopt or reject an innovation, resulting from the activation of peer networks about the innovation in a system. . . . If the first adopter of an innovation discusses it with two other members of the system, each of these two adopters passes the new idea along to two peers, and so forth, the resulting distribution follows a binomial expansion . . . similar to that of an unchecked infectious epidemic.[153]

The same or similar phenomena have been observed by many authors in a wide range of disciplines, so the concept may be familiar under one of its other names: the "bandwagon effect"; "threshold models"; "social contagion"; or, most popularly, "the tipping point."[154] These types of models are ubiquitous in the innovation diffusion field.[155]

1. *The Threshold Theory of Innovation Diffusion*

In order to explore this snowball effect, it is useful to borrow concepts from "agent-based modeling" (ABM). Agent-based

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152 *See* ROGERS, *supra* note 17, at 359.

153 *Id.* at 274 (citing NORMAN T. BAILEY, THE MATHEMATICAL THEORY OF INFECTIOUS DISEASES AND ITS APPLICATIONS (2d ed. 1975)).

154 MALCOLM GLADWELL, THE TIPPING POINT (2002); Eric Abrahamson & Lori Rosenkopf, *Social Network Effects on the Extent of Innovation Diffusion: A Computer Simulation*, 8 ORG. SCI. 289, 295 (1997) ("Bandwagons have a positive feedback loop in which information generated by more adoptions creates a stronger bandwagon pressure, and a stronger bandwagon pressure prompts more adoptions."); Ronald S. Burt, *Social Contagion and Innovation: Cohesions Versus Structural Equivalence*, 92 AM. J. OF SOC. 1287 (1987); Flores et al., *Networks and Collective Action*, 2–3 (Tinbergen Inst., Discussion Paper No. 12-032/1, 2012), *available at* http://hdl.handle.net/10419/87543 ("Threshold models of diffusion of innovations, where individuals are assumed to have different thresholds that determine whether they will adopt an innovation as a function of the number (or proportion) of others in the population who have already adopted it . . . .").

155 *See* Carlos E. Laciana & Nicolás Oteiza-Aguirre, *An Agent Based Multi-Optional Model for the Diffusion of Innovations*, 394 PHYSICA A 254, 255 (2014) (indicating that the two major categories of agent-based diffusion models are threshold models and cascade models, both of which are based significantly on network effects).

models focus on the individual decision-making mechanism of each person or "agent."[156] ABM is particularly useful here since it allows us to focus on consumers' adoption heuristic, the decision-making mechanism used in the model.

Agent-based diffusion models can be broken into two basic categories: cascade models and threshold models.[157] Cascade models are probabilistic and exponential.[158] The probability that a consumer will adopt an innovation increases as the number of his peers who have adopted increases. Threshold models are discrete, using fixed threshold values, instead of probabilistic outcomes.[159] This makes threshold models more straightforward and, therefore, more useful for the illustrative model example used in this Student Article. Because of this, they will be the focus for the remainder of this Section.[160]

In a basic threshold model, each individual is assigned an adoption threshold. An individual's adoption threshold is the number of his peers that must adopt before he will be willing to adopt himself.[161] Earlier adopters belong to segments with lower adoption thresholds, while later adopters belong to segments with higher adoption thresholds. Adoption thresholds are based on the personal characteristics of the consumers, such as financial

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156 Peter Hëdstrom & Peter Bearman, *What Is Analytical Sociology All About? An Introductory Essay, in* THE OXFORD HANDBOOK OF ANALYTICAL SOCIOLOGY 3, 19 (Peter Hëdstrom & Peter Bearman eds., 2009) (providing an introduction to the field of Analytical Sociology and its associated methodology, agent-based models).

157 *See* Laciana & Oteiza-Aguirre, *supra* note 155, at 255 ("[W]e can identify two mayor [sic] categories of agent-based diffusion models: (a) threshold models, in which agents adopt when a specified minimum number of neighbors have adopted, and (b) cascade models, where the probability of adoption increases with the number of adopters in the neighborhood, with an exponential mathematical dependency."); Nishith Pathak et al., *A Generalized Linear Threshold Model for Multiple Cascades*, IEEE INT'L CONF. ON DATA MINING, Paper No. 1550-4786/10, at 965 (2010), *available at* http://www-users.cs.umn.edu/~banerjee/papers/10/gltm.pdf ("Broadly two theoretical models of diffusion have been explored: the linear threshold model and the independent cascade model.").

158 *See* Laciana & Oteiza-Aguirre, *supra* note 155, at 255.

159 *See id.*

160 This is not to say that threshold and cascade models are completely interchangeable. Depending on the context, one of these types of models is likely to be a better match to observed network behavior. However, I believe that the basic insights discussed in this section would apply in both types of models, and the threshold model makes discussion easier.

161 *See* Laciana & Oteiza-Aguirre, *supra* note 155, at 255; ROGERS, *supra* note 17, at 355.

position, appetite for risk, ability to understand "complex technical knowledge," or the value they place on being adventurous.[162] In short, being an "early adopter" is a characteristic of the actor, not the product. This fixed set of early adopters will be more likely to adopt an innovation than their peers will be.

In a successful example of diffusion, the process is like a domino effect—as the number of adopters rises, more individuals' thresholds are met, tipping more individuals into adoption, and increasing the number of adopters.[163] These newest adopters will in turn increase the total number of adopters, triggering more thresholds. For an innovation to become fully adopted, the last group of adopters' thresholds must be met. However, this does not always happen. The diffusion process may reach an equilibrium before full adoption. Consider the process as occurring in rounds—in each round, individuals measure the number of adopters, determine whether their threshold has been met, and decide whether to adopt. In any round, there is some number of new adopters, or individuals who decide to adopt for the first time in that round. The process will reach a stopping point if the number of new adopters in one round is not sufficient to trigger any additional adoption thresholds in the following round.

Observation of peer behavior occurs over a social communication network, or a collection of individuals and the ties between them.[164] Social networks can be visualized as a group of nodes and interconnecting lines. A network can represent many different things; for example, a residential neighborhood, where each node is a household and all neighbors are connected by lines, could form a network. Alternatively, a social network could represent the entire U.S. population, with lines indicating Facebook friendships.

For the purposes of innovation diffusion, the relevant network is one in which the nodes represent individuals in the targeted consumer population and lines represent the transmission of

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162 ROGERS, *supra* note 17, at 357–58; *id.* at 298 (describing characteristics that determine an adopter's innovativeness).

163 For a more detailed description of agent-based modeling and the functioning of threshold-based models, see V. Patrice Wylly, Eco-Friendly or Eco-Trendy: An Investigation of Possible Mechanisms Generating the Popularity of Visible Green Products (Sept. 1, 2010) (unpublished M. Sc. dissertation, University of Oxford) (on file with author).

164 *See* ROGERS, *supra* note 17, at 337 ("A *communication network* consists of interconnected individuals who are linked by patterned flows of information.").

information about the innovation.[165] For example, if Alice purchases an HEV, and Bob parks next to her HEV at work, the network would connect Alice and Bob. This will result in a number of lines connecting Alice with all of the people she parks near. If Chris also owns a Prius and is much more popular than Alice, telling all of his friends about his Prius, and parking next to many more people at his Bowling League, Chess Club, and Dance School than Alice does, Chris will be connected with many more lines to many more people. The end result is that there are many different nodes, with different levels of connectivity. Sophisticated models might add complications. For example, they could distinguish between types of interactions, with thicker lines connecting individuals with stronger exchanges of information, e.g., Alice and her son Dan, versus Alice and her coworker Bob. Alternatively, they could account for the direction of information flow, using vectors instead of lines. For example, if Chris is not much of a talker, but a great listener, all of the arrows could face inwards towards Chris, rather than outward towards his acquaintances. All of these factors will influence the spread of information along the network. Once sufficient information has been spread to an agent such that her adoption threshold is met, she will adopt.

2. *Application of the Threshold Theory to the HEV Tax Credit*

Within the basic threshold model described above, this Subsection compares the success of a technology-neutral and a technology-specific scheme.

For the purposes of a threshold model, the main feature distinguishing the two types of policies is the number of market entrants. To elaborate, under both the technology-neutral and technology-specific policies, the goal is to replace a mature technology, such as combustion engines,[166] with a new innovation,

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165 *See* Flores et al., *supra* note 154, at 2 ("In order to define a dynamical model of collective action it is crucial to understand the role of the social structure in the sharing of information and the formation of opinions. We will assume that the society members are connected through a social network which is the primary conduit of information, opinions, and behaviors . . . .").

166 There were approximately 496 thousand HEVs sold in the U.S. in 2013. *HEV Sales*, *supra* note 109. In comparison, there were nearly 15.6 million total new cars and trucks sold in the same year. *See* Chris Isidore, *Car Sales Make a Strong Comeback in 2013*, CNN MONEY (Jan. 3, 2014, 4:40PM), http://money.cnn.com/2014/01/03/news/companies/car-sales/. Therefore, the vast majority of the population still drives combustion-engine vehicles. When the

or "market entrant." The difference between the two policies is the number of market entrants that would be promoted. Specifically, a tech-neutral scheme would reward a wider range of technologies as compared to a tech-specific scheme. This means that more products would be introduced or promoted in the market. This is the key difference between the two policies, for the purposes of the threshold model. Note that characteristics of the innovations themselves are held constant, in order to focus on the impact of the switch in the number of market entrants.[167]

Within the threshold model, a policy that promotes a larger number of substitute technologies will result in fewer initial adopters of any one technology. This is because the available early adopters—those with low adoption thresholds—would be split among the various technologies. Since the technologies are substitutes, they are assumed to be mutually exclusive. Adopters

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AMVC was first introduced, there were even fewer alternative vehicles on the road.

167 The threshold model example discussed here has been simplified in a number of ways. Because of this, it is worth emphasizing two points about the best way to use the insights from this model.

First, the threshold model example focuses only on the impact of multiple market entrants with a threshold-based decision-making mechanism. This does not mean that the threshold mechanism and number of entrants are the only determinant of an innovation's diffusion rate. Instead, the point is to hold all the other relevant factors constant, isolating the impact of the threshold mechanism under different numbers of market entrants. Section I indicated that technology-neutral policies could result in better innovations. Having already acknowledged this, Section III sets aside the quality of the innovations. Moreover, in both cases, the targeted population is the same: the U.S. population of drivers. Therefore, qualities of the social network are exogenous to the model and should be held constant.

Second, the threshold model discussion is only an example. Simplified examples can be useful in demonstrating diffusion concepts. *E.g.*, ROGERS, *supra* note 17, at 356. Full agent-based models would typically be based on empirically-supported input values and run for thousands of repeated simulations, under varying, randomly-generated assumptions. For example, adoption thresholds might be set based on randomly-generated normal distributions. In contrast, the example here is just one iteration of an agent-based model. The purpose of this model example is not to prove clear conclusions or to make statistically significant claims. Instead, the purpose is to illustrate how the threshold mechanism operates and provide insights into the forces we would expect to see at work in the real world. Because the model is not intended to stand alone, Section II.B.3, introduces some empirical evidence and compares it to the impact predicted in the theoretical threshold model example.

Because of these simplifications, the example is not intended to be a realistic model of expected diffusion rates. Instead, it is designed to isolate and highlight the impact of just one factor in innovation diffusion: number of market entrants.

will pick only one.

With fewer initial adopters of each technology, fewer segments of the population will see their adoption threshold met for any one innovation. As a result, a lower proportion of the population will adopt in the next round. In turn, this will iteratively reduce the chance that agents will adopt in each subsequent round. Therefore, by promoting too many technologies at once, any one innovation will be less likely to diffuse.

To illustrate, consider one hypothetical example of a threshold model simulation. Suppose that there are ten people in a social network. Further suppose that policymakers are deciding whether to use a technology-neutral or a technology-specific subsidy. Under the technology-specific subsidy, they will only promote one vehicle technology, SuperCar. However, a manufacturer is working on another model, GreatMV, which uses a different technology. If policymakers adopt a technology-neutral version of the subsidy, GreatMV will also qualify. The innovations are mutually exclusive substitutes, so consumers will buy only one.

Assume that GreatMV and SuperCar produce identical characteristics in the network – same thresholds, same connectivity, etc.[168] For simplicity, assume that every person in the network is connected to every other. For illustration purposes, the adoption thresholds of each individual are as follows:

Individual	**Adoption Threshold**
Alice	0
Bob	0
Chris	2
Dan	2
Eva	4
Fran	4
George	6
Harry	6

168 *See supra* note 167, for a more detailed explanation for why these characteristics are assumed to be identical.

Ingrid	8
Kevin	8

Scenario 1 – Technology-Specific: Only SuperCar is Promoted

Under the technology-specific policy, only SuperCar receives a subsidy. This will make SuperCar cheaper than GreatMV. Since we have assumed that the cars are otherwise identical, consumers will always prefer SuperCar. Consumers will decide whether or not to adopt SuperCar.

In Round 1, Alice and Bob will adopt. At the start of Round 2, the total number of adopters is two (Alice and Bob), so Chris and Dan will adopt. Round 3 will have Alice, Bob, Chris, and Dan, or four adopters, leading Eva and Fran to adopt. In Round 4, George and Harry's thresholds have been met at six total adopters. They bring the total number of adopters up to eight, and Ingrid and Kevin will adopt, leading to full diffusion.

Scenario 2 – Technology-Neutral: Both SuperCar and GreatMV are Promoted

Under the technology-neutral policy, the government will promote both SuperCar and GreatMV. Consumers will decide whether to adopt SuperCar, adopt GreatMV, or adopt neither.

Alice and Bob are early adopters: both are willing to adopt an alternative vehicle, even when no one else has adopted. They will each adopt an alternative vehicle in Round 1.

If Alice and Bob both choose the same innovation, then we will face the same results as in Scenario 1: whichever innovation they choose will diffuse through the entire population.

But what if Alice and Bob are uncoordinated and each pick a different innovation in the first round? In Round 1, Alice adopts SuperCar and Bob adopts GreatMV. At the start of Round 2, the total number of adopters of SuperCar is one. Other than Alice, only Bob has a threshold less than or equal to one. Bob already has a GreatMV, so he will not buy a SuperCar. Therefore, no new individuals will adopt SuperCar in Round 2. The same result occurs for GreatMV. Therefore, there will be no new adopters, and the total number of adopters of any innovation will be two.

This means that there are two potential outcomes under the technology-neutral scenario: (1) the innovation fully diffuses; or (2) only early adopters buy a green car. In comparison, under the technology-specific scenario, there is always full diffusion. The same population, with the same set of adoption thresholds, makes different choices—with very different final outcomes—under the two scenarios. With a technology-specific policy, the innovation always diffuses in our example. With a technology-neutral policy, the innovation only diffuses in half of the possible outcomes, leaving the result to chance.

In sum, all else being equal, if there are more innovations on the market at once, they will be less likely to fully diffuse through the population. By extension, encouraging multiple innovations at once will also be less likely to result in high adoption rates. Tying this back to the underlying issue, this is because the diffusion snowball is caused by the tendency for adopters to pass information along social networks to non-adopters.[169] With multiple market entrants, capacity for transmitting information is split among the multiple market entrants. As a result, less information is passed about any one technology, allowing uncertainty and risk to discourage potential adopters. The chances of a snowball are decreased.

This example demonstrates that, if individuals are making innovation adoption decisions using heuristics that are based on peers' behavior, then a tech-neutral credit might be less likely to encourage mass adoption than a tech-specific credit. Therefore, although tech neutrality might encourage innovation by the industry, it could discourage adoption by consumers. Empirical support for this intuition is discussed in more detail in Section III.A.3.

3. *Empirical Evaluation of the Threshold Example: The Standard War*

The above threshold model example indicates that multiple market entrants could decrease the information passed about any one innovation and reduce the chances of either innovation snowballing. If so, the pre-existing, mature technology would continue to dominate the market. This Subsection draws a parallel between the theoretical insights described above and economic research into another real-world phenomenon: "Standard Wars." Research on Standard Wars indicates that multiple entrants can increase uncertainty and delay mainstream adoption.

A Standard War takes place when a number of rival

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169 *See* ROGERS, *supra* note 17, at 211–12.

technologies emerge on the market and compete to become the new standard.[170] Standard Wars can occur when two conditions are met: (1) the standards are incompatible; and (2) "network externalities" play a role.[171] As mentioned above, HEVs are substitutes for traditional vehicles, so condition (1) is met.

Condition (2) is also met here. Network effects mean that a technology becomes more valuable as more people use it.[172] The Internet is a commonly-cited example: if no one else adopts the internet, it is of little value to me. However, there are actually two types of network effects:

> There are *direct* network externalities: e.g., every new fax machine increases the reach of network; and *indirect* network externalities: e.g., if everyone buys the same car brand, the number of dealers and the availability of spare parts will be higher.[173]

It seems at least as likely that different vehicle *technologies* would face these indirect network effects, if different vehicle brands do.[174] Therefore, indirect network effects are a consideration here.

Research into Standard Wars indicates that Wars reduce information about the rival innovations on the market: the market will become "less transparent" and the war will "create uncertainty."[175] This can lead to significant delays in adoption and can hinder innovation.[176] Producers and consumers who are

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170 *See* Victor Stango, *The Economics of Standards Wars,* 3 R. NETWORK ECON. 1, 2 (2004) ("Standards are interesting from an economic standpoint because many markets face a strong trend toward *standardization* – the adoption of a common standard by all market participants. This leads markets toward "winner-take-all" outcomes where a single standard emerges victorious, while the others disappear. These battles are known as *standards wars*.").

171 Egyedi, *supra* note 24, at 17–18.

172 *See id.*

173 *Id.* at 18.

174 It seems, if anything, more likely that there would be differences between the spare parts needed for HEVs and electric fuel vehicles than between two different brands of vehicles. The magnitude of the indirect network effects may also be stronger between technologies, for example, if there are some types of parts that can be exchanged between vehicle brands but not between vehicle technologies. On the other hand, it is also possible that the network effects are no larger for vehicle technologies than for vehicle brands. Whether a part fits is binary: it either fits or it does not. Therefore, it may not be meaningful to try to determine whether the part is "more wrong" when dealing with different technologies. It suffices to say that indirect network externalities are very likely to be present for vehicle technologies, since they are for vehicle brands.

175 *Id.* at 20.

176 *See id.*

uncertain about the War's outcome will hesitate to invest:

> The uncertain outcome of wars between rival revolutions is a key intermediate factor in determining their impact. It undermines competition and leads to a hold–up of investments: producers will try to postpone investments for fear of investing in a 'losing' system and having to write off sunk costs (i.e., costs that are specific and irreversible, and therefore cannot be retrieved). The same hesitations exist on the side of consumers. They will postpone their purchases. The market will stagnate. An example is the recent war between Blu-ray and HD-DVD. The market for High Density DVDs stagnated because consumers feared to be left with a 'losing' system and therefore postponed their purchases.[177]

In short, a War between market entrants will hinder the adoption of either technology.

Moreover, there is evidence that the winners of these standard wars are not always the better technology.[178] For example, many argue that the QWERTY keyboard is not the best possible keyboard arrangement.[179] Yet, QWERTY was the winner of the

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177 *Id.* at 19 (citing Joseph Farrell & Garth Saloner, *Installed Based and Compatibility: Innovation, Product Preannouncements, and Predation*, 76 AM. ECON. R. 943 (1986); Oliver Williamson, *Transactions-Cost Economics: The Governance of Contractual Relations*, 22 J. L. & ECON. 233 (1979)).

178 *See id.* at 20 ("[S]tandards wars . . . need not necessarily lead to 'superior' outcomes").

179 *See* Stango, *supra* note 170, at 7 ("An influential paper by David (1985) argues that the QWERTY keyboard design was chosen early in the market but is inefficient given current standard. In particular, the QWERTY keyboard is designed to minimize key sticking on manual typewriters. The thrust of the argument is that this is no longer a concern. Because computer keyboards cannot stick, there is no gain to a design that minimizes key sticking. Furthermore, the argument is that superior alternatives to the QWERTY design exist in terms of learning costs and ultimate typing speed, and that the costs of switching are vastly outweighed by the benefits. This implies that the market is locked in to an inferior standard." (citing P. David, *CLIO and the Economics of QWERTY*, 75 AMER. ECON. R. 332 (1985)). However, it is worth noting that some disagree with this claim and argue that there may not actually be any better alternative keyboard available. *Id.* at 8 ("[T]he validity of the QWERTY story has come under question. Liebowitz and Margolis (1990) present contrary evidence suggesting that the superiority of alternative keyboards has never been firmly established. They note that classic tests of the leading alternative (the 'Dvorak') are in retrospect inconclusive and possibly tainted by the influence of Dvorak himself, who held a patent on his design. Nor is the critique restricted to the QWERTY example. Arguments have also been made that Betamax was in fact an inferior VCR standard and that this, rather than lock-in and inertia, explains the dominance of VHS. Unfortunately, the arguments above are based on somewhat anecdotal evidence. Given the paucity of hard evidence regarding the QWERTY case, it is unlikely that the debate can ever be resolved conclusively."

Standard War for keyboard design.[180] Similarly, William H. Redmond analyzed data from the VCR market, as Sony and Matsushita competed to establish the dominant standard in the 1970s.[181] Redmond found that "luck" may have played a role in the outcome of the War because of the self-reinforcing (snowball) effect of innovation diffusion.[182] This mirrors the element of chance that was illustrated in the threshold model example in Section III.A.2. Redmond emphasized that "one cannot predict in advance which technology will dominate; the eventual winner is not guaranteed to be the 'best' technological solution."[183]

In sum, Standard Wars often delay the diffusion of a new technology. This should lead us to be concerned that a tech-neutral policy could similarly slow adoption rates, as multiple alternative vehicle technologies battle to dominate the market. Consumers do not want to "pick winners," risking that they will make the wrong choice, any more than governments do.

Worse, we should be concerned that a Standard War could not only delay, but actually prevent diffusion in the case of green technologies. The market for green technologies is much more complicated than the market for home entertainment discussed above. There are fewer externalities associated with a DVD player than an automobile. The elevated levels of uncertainty and risk associated with the alternative vehicle market could result in Standard Wars with even more harmful effects.

Lastly, Standard War research indicates that the presence of multiple market entrants could actually undermine the entire purpose of a technology-neutral policy. The main goal of a technology-neutral policy is to ensure that the "best" technology is chosen. However, as QWERTY keyboards show us, Standard Wars are not always won by the best technology. Therefore, not only are there costs associated with a technology-neutral policy, but the expected benefits of a technology-neutral policy might never be realized.

(citing Liebowitz, S. J. and S. E. Margolis, *The Fable of the Keys*, 33 J. OF L. & ECON. 1 (1990)).

180 *Id.* at 7.

181 *See* Redmond, *supra* note 20, at 177–78.

182 *Id.* at 170 ("One intriguing aspect of nonlinear market processes is a propensity for small, outside influences to exercise a powerful and long-term influence on market response, that is, "luck" may play a role in these models."). For a more detailed explanation, see *id.* at 182.

183 *Id.*

B. *Product Visibility: Taking Advantage of Diffusion by Targeting Observable Innovations*

To this point, the discussion in this Student Article has focused on the spread of information over adoption networks, holding the characteristics of the innovations themselves constant. This is because the discussion focused on a switch from the AMVC to a technology-neutral version. Under a technology-neutral policy, the government does not pick technologies, so the qualities of the innovations are outside of our control. Were the United States to adopt a technology-neutral version of the AMVC, the characteristics of the innovations that would qualify for the AMVC would be unspecified and unpredictable.

But suppose that we consider designing a new tax credit. A technology-neutral version would still not be able to control an innovation's characteristics. However, a technology-specific policy would allow us to determine the innovation's characteristics. Specifically, we could purposefully promote a "visible" technology, i.e., one that is conspicuous, easily observed, and readily identified.

In the case of the AMVC, the fact that the credit supported a visible technology was a "happy accident." HEVs qualified for the AMVC, and they are highly visible. More precisely, the Toyota Prius is visible, and it is the dominant HEV on the market. The Prius was crafted to be a visible car. It was designed "from scratch so it looks like nothing else on the road."[184] Its appearance has been called "unmistakable."[185] Moreover, the Prius is dominant in a number of ways. First, it has superior brand recognition: as a New York Times headline puts it, "[s]ay 'Hybrid' and many will hear 'Prius.'"[186] Second, it was among the first to the market.[187] Lastly, it vastly outsells its competitors, particularly in HEVs' earlier years.[188]

Future green tax credits could be purposefully designed to support visible innovations. This is desirable because visibility is key to social network influences, as explained below. In turn,

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184 PRIDE, *supra* note 26, at 207.

185 *Id.*

186 Micheline Maynard, *Say 'Hybrid' and Many People Will Hear 'Prius'*, N.Y. TIMES, July 4, 2007, at A1, *available at* http://www.nytimes.com/2007/07/04/business/04hybrid.html.

187 *See HEV Sales*, *supra* note 109.

188 *See id.*

social network influences promote diffusion of green innovations, as discussion in Section II. Therefore, the ability to support high-visibility innovations over low-visibility innovations is one advantage of technology-specific policies over technology-neutral ones. Foregoing this ability is a cost of technology neutrality.[189]

1. *What Is Visibility?*

This Student Article uses the term "visibility" to mean a product or technology that is highly observable, i.e., it is easy for others to notice and recognize the innovation once it is adopted. In terms of social networks, this means that an individual who adopts a visible innovation will pass awareness and knowledge of the product onto more of his network connections. In an agent-based model, a network representing information transmitted about a visible product would have high connectivity—there would be many lines connecting nodes. In short, more visible innovations spread more social information.

It is worth noting that a product could be visible in one of two ways: a technology could be inherently highly visible, like wind turbines, or it could have a design that is purposefully contrived to be visible, like the Toyota Prius. Although much of this Article focuses on the Prius as an example of visibility, there is reason to expect that inherently visible products could be even more successful. An inherently visible technology is, for the most part, self-proving: if there are big fans on your roof, it is fairly clear that you are using a green technology.

However, designs can be more easily faked. "Greenwashing," which is "the practice of attaching a positive environmental association with an unsustainable product of service," can lead to

[189] Section I indicated that technology-neutral policies could spur better technologies. This has led some to comment that the market itself would select visible technologies if visible products have a market advantage. There are two reasons we should be skeptical about this. First, as discussed in Section II.A.3, Standard Wars do not always select for the better product. Second, tax subsidies are often used to promote the development of substitute technologies. For example, HEVs are a substitute for traditional vehicles. This means that the existing industry—i.e., traditional car manufacturers—has no incentive to encourage the switch from traditional to green vehicles. Toyota is presumably just as happy to sell you a Rav 4 as a Prius. Since these green products are often substitutes for mature technologies, only new industry entrants would have an incentive to design the product in a way that encourages consumers to switch technologies. These break-in producers are at a disadvantage as compared to established producers and are therefore even more likely to lose a Standard War.

misinformation about a product's environmental impact.[190] In turn, when consumers suspect that a company is greenwashing, they are less likely to purchase the product.[191] Since an inherently visible technology is more difficult to fake than a contrived design, it could help to allay consumer's concerns and promote adoption. If, as this Section will conclude, policymakers could use product visibility to their advantage when designing innovation incentives, inherently visible technologies may be the better bet.[192]

2. *Why Is Visibility Important?: Social Learning Heuristics Versus Conspicuous Conservation*

Given that visible innovations will spread more information along social networks, there are two possible explanations for the importance of visibility in product diffusion: Social Learning or Conspicuous Conservation.[193]

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190 Phil Covington, *Is It Greenwashing Or Too Many Eco-Labels That Is The Problem?* TRIPLE PUNDIT (Mar. 22, 2011), http://www.triplepundit.com/2011/03/greenwashing-many-eco-labels-problem/

191 *See* Horiuchi et al., *Understanding and Preventing Greenwash: A Business Guide*, BSR & FUTURA SUSTAINABILITY COMM. 14 (July 2009), http://www.bsr.org/reports/Understanding__Preventing_Greenwash.pdf ("Customers have the power to put their money where their mouths are. People who care about the environment will not buy products from a company they feel is greenwashing . . . . In a January 2009 survey of more than 20,000 consumers worldwide, Havas Media found that 64 percent saw sustainability as a 'marketing tool' and often did not trust brands' claims. The same study revealed that almost half of the surveyed group would pay 10 percent more for more sustainable products, despite the state of the economy. In other words, the very customers who want these products do not trust the messages that promote them.").

192 Inherently visible technologies might have some normative advantages too. In particular, since conspicuous designs are not necessary and might incur additional costs, encouraging manufacturers to create eccentric-looking products could be considered wasteful or manipulative.

193 *See* Janssen & Jager, *supra* note 27, at 344 ("Two basic mechanisms are assumed to underlie the social process that can be witnessed in markets. In the first mechanism, the product choice of other people provides a practical heuristic to limit the set of options to choose between. Especially in conditions of uncertainty, people tend to observe the behavior of others to quickly find out about attractive solutions for a decision problem. In particular, the behavior of people similar on a relevant dimension (e.g., income) may provide valuable information. The more people perform a particular behavior, the more frequently it will be observed, resulting in a self-reinforcing process propagating the behavior . . . . Theories and concepts that relate to this type of mechanism are social learning and imitation, social comparison, and norms. The second mechanism we distinguish is based on social needs that people have. People have needs to belong to a group (belongingness) and express their status and personality (identity). Hence using a certain product may have extra value

a. *Social Learning Heuristic*

As discussed earlier in this Student Article, innovation diffusion patterns are self-reinforcing, as consumers use decision-making heuristics based on information passed along social networks. This process has sometimes been called "social" or "vicarious" learning.[194] Taking a closer look at social learning reveals that more visible innovations fare better on this adoption heuristic.

Consider a simple illustration. Imagine looking for a place to eat dinner. As you walk past a restaurant, you see a line trailing out the door. Based on this crowd, you decide that the restaurant must be worth the wait, and you get in line to eat there too. This is the essence of social learning: you have made a decision regarding where to eat based on your perception of others' behavior.

Under a social learning heuristic, more visible products will spread more easily. This is because more visible products are more easily observed by peers, spreading information and facilitating learning. Imagine this as the difference between a restaurant with a line inside and a restaurant with a line out the door. You are more likely to observe, and therefore learn about, the quality of the restaurant with the line outside. In terms of the threshold model discussed in Section III.A, a visible product would be observed by every agent in the network, while a less visible product would only be observed by some. Because visible products are observed more readily, they transmit more information, and the innovation is more likely to be adopted.

Consider the solar panel example mentioned in Section II.C. Rogers observed that solar water-heating occurred in residential clusters in California neighborhoods.[195] This clustering effect was subsequently attributed to the tendency for neighbors to "observe and discuss the costs and benefits of installing this technology."[196] Suppose solar panels were located inside basements, rather than on rooftops. It would be hard to imagine that neighbors would be likely to observe and discuss solar water-heating under these conditions. Because solar panels are observable, social learning

because a particular group of people is already using it . . . . The approaches of Veblen and successors mainly focus on this second mechanism.").

194 TIDD, *supra* note 134, at 24–26. *See also* Michael W. Macy, *Learning Theory and the Logic of Critical Mass*, 55 AM. SOCIOLOGICAL R. 809, 811–812 (1990).

195 *See* ROGERS, *supra* note 136, at 303–04 (1983).

196 Roy, *supra* note 137, at 44.

could occur.

b. *Conspicuous Conservation*

There is another possible explanation for why visibility is important that is also consistent with the "snowball" phenomenon.[197] This explanation relates to a desire to express status or identity through adoption.[198] Under this mechanism, "conspicuous conservation" can explain why product visibility will encourage diffusion.[199]

The theory of conspicuous conservation indicates that green purchases can be used to demonstrate high social status. This is a parallel to Veblen's concept of conspicuous consumption: by wasting resources through luxury purchases, the consumer demonstrates that he has an excess of resources.[200] In the context of conspicuous conservation, the consumer gets a double boost to his prestige: (1) green products are generally more expensive, so they provide a traditional conspicuous consumption benefit, and (2) green products show that the consumer is altruistic, sacrificing his own resources for the benefit of others.[201] Multiple surveys indicate that the Prius' popularity can be, at least in part, attributed to conspicuous conservation motives.[202]

For conspicuous consumption/conservation purposes, sending a signal that the actor is purchasing the status good is fundamental.[203] Because visible products will be more easily

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197 *See* Janssen and Jager, *supra* note 27, at 344 (indicating that social learning and conspicuous consumption are the two mechanisms usually used to explain the social aspect of market choices).

198 *See id.*

199 *See generally* Griskevicius et al., *supra* note 27.

200 *See* THORNSTEIN BUNDE VEBLEN, THE THEORY OF THE LEISURE CLASS (2007).

201 *See* Griskevicius et al., *supra* note 27, at 392-94.

202 This explanation has been touted by media sources varying from New York Times, *see* Maynard, *supra* note 180, to "Treehugger.com," Dominic Muren, *Pop Quiz: Why People like Prius*, TREEHUGGER.COM (May 27, 2008), http://www.treehugger.com/culture/pop-quiz-why-people-like-prius.html; *see also* Randall Parker, *Prius Appeals as Personal Statement*, FUTUREPUNDIT (July 26, 2007), http://www.futurepundit.com/archives/004372.html. It is also supported by academic studies. *E.g.*, Griskevicius et al., *supra* note 27.

203 *See* Ulrich Witt, *Symbolic Consumption and the Social Construction of Product Characteristics*, 21 STRUCTURAL CHANGE & ECON. DYNAMICS 17 (2009) ("As recognized since long, consumption serving to signal social status, group membership, or self-esteem is a socially contingent activity. The corresponding expenditures are motivated mainly by the symbolic value they have for transmitting the signal. However, this presupposes some form of social

observed, they will send a stronger signal. This makes them more valuable as a status good.[204] If visible innovations have more value to consumers, then these innovations will be more likely to be adopted.

For the purposes of this Student Article, it is not important to decide which of these mechanisms is the driving force behind the popularity of visible green products. In all likelihood, some combination of the two is occurring.[205] For now, the relevant fact is that visibility matters. The following Subsection provides evidence of this fact.

3. *Evidence of the Importance of Visibility*

The claim that visibility improves innovation diffusion is empirically supported across a number of topics.

First, there is general support for the importance of visibility in innovation diffusion research. Rogers himself provides evidence of visibility's impact in his study of the adoption of agricultural innovations. Specifically, in his study on agricultural innovation adoption rates, Rogers identified five "perceived characteristics" of innovations that were key to adoption.[206] One of these characteristics is "observability."[207] Rogers indicated that ideas that can be "easily observed and communicated to other people" will be more likely to diffuse.[208] Those that are less communicable will be slower to diffuse:

> One example is "safer sex," the preventive approach recommended to individuals by health experts to avoid contracting HIV/AIDS. Safer sex is a rather ambiguous idea, including abstinence and sexual monogamy as well as the specific behavior of using condoms. As a result, the preventive innovation of safer sex has spread slowly and to a relatively

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coordination on what are valid, approved symbols. Unlike consumption not serving signaling purposes, the technological characteristics of the goods and services consumed may be secondary—what counts is their socially agreed capacity to function as a symbol.").

204 *See* Griskevicius et al., *supra* note 27.

205 For a more detailed comparison of the two mechanisms, see Wylly, *supra* note 163.

206 ROGERS, *supra* note 17, at 223 ("[The] five attributes of innovations are (1) relative advantage, (2) compatibility, (3) complexity, (4) trialability, and (5) observability.").

207 *Id.* at 258–59.

208 *Id.*

> small percentage of all individuals at risk for HIV/AIDS.[209]

This observation has been repeatedly replicated: Rogers reviews a number of prior and subsequent authors who found similar results in the most recent edition of his classic work.[210] Moreover, other researchers have replicated these results in different innovation contexts.[211] For example, a study of uptake of the Canadian Heart Health Kit indicated that Rogers's five perceived characteristics were positively and significantly correlated with adoption, particularly "relative advantage" and "observability."[212] Moreover, the study found that observability was particularly influential.[213] A study of internet banking produced similar results. The study found three relevant characteristics to be significant predictors of adoption rates: relative advantage; "result demonstrability" and "image," which could be tied to a conspicuous conservation explanation; and "trialability."[214] Moreover, the study found that relative advantage was the *least* significant of the three factors.[215]

There is also support for the claim that visibility matters in the context of green innovations. In a discussion of home energy choices, one commentator indicates that:

> Visibility is a key feature of renovations, as it mediates the influence of social norms on homeowners' motivations. Social norms are an important feature in technology diffusion models and sociological models of patterned or structured behavior. Social norms can also be a powerful influence on pro-environmental behavior and are explicitly targeted by social marketing interventions. Behaviors can be supported

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209 *Id.*

210 *See* ROGERS, *supra* note 17, at 223–25.

211 *E.g.*, Shannon D. Scott et al., *Factors Influencing the Adoption of an Innovation: An Examination of the Uptake of the Canadian Heart Health Kit (HHK)*, 3 IMPLEMENTATION SCI. 41 (2008); Spiros Gounaris & Christos Koritos, *Using the Extended Innovation Attributes Framework and Consumer Personal Characteristics as Predictors of Internet Banking Adoption*, 13 J. FIN. SERVS. MKTG. 39, 47 (2008).

212 Scott et al., *supra* note 211, at 46 ("This study found two of its attributes to be more influential than the others, namely relative advantage and observability.").

213 *Id*. They also found that "relative advantage" was particularly influential. One of the sub-characteristics within relative advantage is prestige, which bolsters the importance of the conspicuous conservation explanation. *Id.*

214 Gounaris & Koritos, *supra* note 211.

215 *Id.*

> normatively if they can be demonstrated, observed, compared, and subjected to feedback. Visibility is therefore an important characteristic of normative behaviors.[216]

In short, social network influence is important for diffusion of any innovation, but can be particularly potent for green innovations.

Lastly, multiple studies have shown that consumers prefer visibility in prestige products in general, and specifically in green prestige products. Evidence that buyers place value on visibility for prestige products can be found in a study of women's cosmetics.[217] The study found that women were willing to pay more for cosmetics that they would apply in public, than for those they would apply in private.[218] Similarly, Griskevicius and colleagues ran a study asking subjects to make hypothetical choices between green products and luxury substitutes that were not green.[219] When subjects were told to imagine they were making the purchase in public, then subjects who were "status-primed"—i.e., instructed to read an essay designed to make them be status-conscious during the experiment—were more likely to choose green products.[220] Status priming did not have this effect when subjects were told to imagine making a private, online purchase.[221]

These results suggest that the Prius' visibility has boosted its adoption rates. Although the AMVC was not consciously designed to promote a visible product, future tax credits could make a more purposeful choice to support visible technologies. As discussed in Section III.B.1, the effect could be even stronger if inherently visible technologies were chosen, rather than products with artificially visible designs. Given the importance of visibility, this could bolster future credits' efficacy. However, technology-neutral policies cannot "pick winners," preventing them from favoring visible technologies to harness these social network effects.

C. *Summary of Social Information Issues*

So far, Section III has explained that information is key in

216 Charlie Wilson, *Social Norms and Policies to Promote Energy Efficiency in the Home*, 38 ENVTL. L. REP. NEWS & ANALYSIS 10882, 10884–85 (2008).

217 *See* JULIET B. SCHOR, THE OVERSPENT AMERICAN: WHY WE WANT WHAT WE DON'T NEED 45–53 (1998).

218 *See id.*

219 *See* Griskevicius et al., *supra* note 27, at 396–97.

220 *Id.*

221 *See id.*

consumers' decision to adopt innovations. In particular, information obtained over social networks has the strongest impact. Adoption decisions rely heavily on observations of peer behavior and communication with peers.

As a result, policies that increase social information will be more likely increase adoption rates. Technology-specific policies can better increase social information for two reasons. One, by introducing only one market entrant, the policy will increase the information about that entrant that is shared across the network. In comparison, a technology-neutral policy will split the social network's capacity for information sharing among a number of entrants, reducing the total information about any one entrant.

Two, technology-specific policies can target visible innovations. Because visible innovations are more easily observed, social networks can more readily pass along social information about visible products. Again, this will facilitate the spread of social information and could increase consumer adoption rates.

CONCLUSION: DO THE COSTS OF TECH-NEUTRALITY OUTWEIGH ITS BENEFITS?

Technology-neutral tax incentives allow the industry and the market to have more flexibility than they would under technology-specific incentives. This frees innovators to develop a wider range of innovations that will qualify for the subsidy and avoids "locking" the market into a government-selected technology, which may not necessarily provide the best solution. Because of these benefits, the principle of technology neutrality seems to have become as unassailable as "motherhood and apple pie."[222]

However, this Student Article presented two substantial costs that are also associated with technology neutrality. First, because technology neutrality promotes multiple, simultaneous market entrants, it dilutes the information that is passed along social networks about any one technology. This can undermine the self-reinforcing snowball effect that is key to successful diffusion. In addition, empirical evidence suggests that multiple market entrants often become embroiled in Standard Wars. These Wars are known to delay consumer adoption among the competing technologies. Standard Wars are common for home electronics, like keyboards and television recording systems. In the case of green

222 Reed, *supra* note 4, at 266.

technologies, mired in greater uncertainty and subject to externality problems, the results could be even worse.

Second, technology-neutral incentives cannot be used to subsidize particular technologies. This means that technology-neutral policies cannot be targeted at products with desirable qualities, such as visibility. In contrast, a technology-specific credit could be used to support visible technologies. Consumers generally prefer visible green products over more private ones. Technology-specific policies can capitalize on these benefits of visibility by promoting visible products. Technology-neutral policies cannot employ this strategy. This represents another cost of tech neutrality.

This Article points out that it is important to recognize the costs of technology-neutral tactics along with the benefits. The question in any policy decision must be whether the benefits outweigh the costs. The answer depends on the particular policy goal in mind. Future research will be required to evaluate the strength of social network influences on diffusion in the given context and to decide whether technology neutrality is worth its costs.

Although the cost-benefit analysis of tech neutrality is context-dependent, it is possible to draw some general conclusions. This Article suggests that there are some characteristics of innovations that we would expect to elevate the costs or minimize the benefits of tech neutrality. Most essentially, technologies may be bad candidates for technology-neutral promotion policies if they are substitutes, such that consumers will purchase only one alternative. This can be exacerbated if (1) the technologies are long-term consumer durables; (2) the products are high cost; or (3) consumers perceive a high degree of uncertainty and risk. Moreover, the greater the network effect for the products, the more likely that a Standard War could prevent adoption of the best technology, reducing the benefits of technology neutrality.

If an innovation is mutually exclusive with other technologies that accomplish the same policy goal, then a technology-neutral policy will promote competing substitute products. If the technologies are substitutes, then once the consumer buys one option, he will not buy another for the period that he owns the first. This is the crux of the information diffusion problem in technology-neutral policies: if consumers must pick only one choice out of multiple technologies, there will be less social information available about each technology. Because the consumer is using only one product during this period, he will carry information to his peers about only one of the technologies. For example, a consumer who purchases a Prius will be unlikely to buy another car model, and will not pass information about any other green vehicle for years. This provides less information to his social network than if he had purchased more than one innovation in that time. As described in Section II*,* less peer information leads to less diffusion. Technology neutrality can slow diffusion in these cases.

In comparison, if a policy promotes a range of green technologies that are not substitutes, then consumers may buy more than one at the same time. Consider a technology-neutral policy designed to reduce home energy usage. A consumer could purchase solar panels and home insulation, both of which reduce energy consumption. A consumer will be able to pass information to his peers about both of these innovations at the same time. The total amount of social information that can be spread is not limited, as it is when the technologies are mutually-exclusive substitutes. In this case, technology neutrality may have a lower cost in terms of reduced adoption rates.

Long-term use and high price can exacerbate the problem caused by substitutes. If the innovation is a long-term durable good, then purchases will be made less often. If purchases are made infrequently, the flow of information will be limited for the entire period that the consumer owns the durable good. In contrast, if purchases are made frequently, consumers can switch among the options. For example, if a consumer buys a reusable coffee cup, she might buy a new one again fairly quickly. For longer-term purchases, information flow will be restricted for greater periods of time, reducing the total volume of information passed. Similarly, consumers may be more likely to purchase multiples if a good is low-price—e.g., reusable shopping bags—than if it is higher price—e.g., green cars. Essentially, if a consumer is more likely to choose only one innovation, total information transfer about each innovation will be reduced, and diffusion will be slowed.

Technologies with higher perceived risk and uncertainty are also worse candidates for technology-neutral policies. With greater uncertainty and risk, there is a need for more information to combat these failures. As information becomes more important, policies that reduce information—like technology neutrality does—become more costly. For example, compare a green dishwashing solution with a green water-heating system. The negative impact of a failed dishwashing detergent—running the dishwasher a second time—is likely to be considered less of an inconvenience than the cost of a failed water-heating system—i.e., a cold shower in the morning. Price also has an impact here: lower prices will present less financial risk to consumers. Social network information will be most important in these contexts, in order to combat the perception of risk and uncertainty. Therefore, technology-neutral policies, which reduce social network information, will be more costly for innovations that are perceived as high risk or whose characteristics are exceptionally uncertain.

Lastly, greater direct or indirect network effects increase the chances that multiple market entrants would enter a Standard War. In turn, a Standard War decreases the chances that consumers will choose the "right" technology. Standard Wars undermine the essential point of technology neutrality. Tech neutrality's most key benefit is that it allows the market to select for the most efficient solution, like the chronometer. A Standard War leaves the outcome to luck. If consumers were choosing which longitude technique to use, they may have chosen lunar maps. Therefore, in the case of innovations with strong network effects, technology neutrality may not lead to more efficient technologies. The primary expected benefit of technology neutrality may be entirely lost.

In the end, do the costs of technology neutrality outweigh the benefits? The answer is, very succinctly: it depends. Future research should quantify the impact of social network influences on diffusion rates. These are likely to be highly context-dependent: different technologies will be more or less dependent on social snowballing. Like any decision, the costs of a switch to tech neutrality must be weighed against the benefits, in the context of each innovation in question. The point of this Student Article is to emphasize that we do not yet know the costs and limits of technology neutrality. If we are to adopt tech-neutral approaches, we should first fully evaluate what we lose along with what we gain.