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POWER FAILURE

An Examination into the Political Economy of the Electric Vehicle

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Introduction

In the late 1890s and early 1900s, the electric vehicle (EV) stood poised, ready to become the world's vehicle of choice to succeed the horse-and-carriage. By the late 1920s, however, it was clear that the EV had yielded to its arch rival - the internal combustion engine vehicle (ICEV). Since this time, numerous opportunities for the resurgence of the EV have presented themselves, including the oil crises of the 1970s and the environmental movement of the 1970s and 1980s. These opportunities have also failed to give way to the EV. Most recently, California announced its zero emissions vehicle (ZEV) mandate, requiring that a growing percentage of each major automaker's sales in California be ZEVs. The required percentage is set at 2 percent for 1998, increasing to 5 percent in 2001 and 10 percent in 2003[1]. Again, however, the fate of the EV remains questionable, as automakers have persistently resisted the ZEV mandate, and consumers remain reluctant to adopt the new technology[2].

This paper will explore the political economy of the EV, and attempt to determine the reasons behind its chronic failure to become a mainstream technology. Although the paper will focus on the last decade, the earlier historical periods of importance to the EV (late 1800s, early 1900s, and the 1970s), will serve as valuable guide in interpreting present trends.

A common view represented in the popular discourse on this topic, is that EVs have failed simply due to a lack of technology: the technological constraint

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[1] EVs are the only technological alternative for automakers to meet the ZEV mandate, since no other zero emission vehicle technologies are workable at the current time.

[2] Noel Perrin, Life with and Electric Car Sierra Club Books, San Francisco, 1994, p.198.

theory.[3] Some maintain that vested interests, such as the major automakers and oil companies, have collaborated to ensure the survival of the auto-industrial complex and the longevity of the ICEV: the conspiracy theory.[4] Still others claim that the EV has never become popular because it cannot match the performance of the ICEV: the consumerist theory[5]. The findings of this paper suggest that all of these responses are incomplete. There is no one overwhelming cause for the failure of the EV. To rely on one response is to divorce the failure of the EV from the larger socio-political framework in which it has evolved.

The literature on the political economy of technology distinguishes between the phases of technological change. For purposes of this paper, it is assumed that the EV represents an innovation that has not yet been widely diffused. Furthermore, the EV is a radical innovation, because it represents a significant break with the past. The EV is not merely an extension of the ICEV; it challenges fundamentally the hegemony of current automotive technology. Essentially, then, the EV embodies a new technological trajectory. As with any new environmental technological trajectory, there are many impediments operating in a multiplicative and highly interactive nature. This paper examines these impediments to a new technological trajectory, and applies them to the case of the EV. The preponderance of these factors stem from Kemp and Soete's `selection environment'. `Selection environment' emphasizes "the institutions involved and the mechanisms behind the selection of an innovation," and recognizes that "innovations [are] embedded in a technoeconomic system (which involves socioinstitutional elements).[6]"

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[3] See for example, Deborah Gordon, Steering A New Course: Transportation, Energy and the Environment, Union of Concerned Scientists, Washington D.C., 1991, p.96.

[4] See for example, Freund and Martin, The Ecology of the Automobile, Black Rose Books, Montreal, 1993, p.136.

[5] See Michael Brian Schiffer, Taking Charge: The Electric Automobile in America, Smithsonian Institution Press, Washington and London, pp.1-4.

[6] Kemp and Soete, 1992, p.445. The term `selection environment' is borrowed from Nelson and Winter (1977).

The paper concludes that failure for the dispersion of EV technology can be traced to a number of factors, including costs to industry and concern over profitability, apprehension over appropriability conditions, lack of technological opportunities and technological feasibility, a shortage of research and development, and consumer resistance. Factors in which there is mixed evidence (i.e. in which the impediment is not clear-cut) include, the mode of regulation, the effect of `clusters of technological trajectories', and market structure.

The first section of this paper will offer a brief history of the EV. The second section will take a detailed look at the factors which have impeded the diffusion of EV technology. The factors in which there is mixed evidence will be presented in the third section. This will be followed by a summary and some policy implications.

A Brief History of the Electric Vehicle

The development of the EV has been a history of peaks and troughs. From the first EV ever built in 1873 to General Motor's sporty 1991 Impact, this technology has continuously come in and out of the market, never quite able to solidify its position amongst automakers and drivers.

By the end of the nineteenth century, EVs actually constituted the mainstream in automotive development. Of the automobiles manufactured in the US in 1900, 1,575 were EVs, and only 936 units were gasoline powered.[7] With continuing improvements in the performance of the ICEVs and persistent limitations in battery technology, however, the gap between the performance of EVs and ICEVs widened. The appearance of the Ford Model T in 1909 heralded the popularisation of ICEVs and their long domination of the market. By the 1930s, despite a combined effort of both Thomas Edison and Henry Ford himself, the EV had disappeared from the mainstream market.[8]

The EV regained some popularity in Japan during the mid-1930s when wartime restrictions on the use of gasoline became severe, and again in the US and

[7] International Energy Agency, Electric Vehicles: Technology Performance and Potential, OECD, 1993, p.19.

[8] Ernest H. Wakefield, History of the Electric Automobile, Society of Automotive Engineers Ltd., 1994, pp.211-224; see also Michael Brian Schiffer, 1994, pp.153-174; and Sheldon Shacket, The Complete Book of Electric Vehicles, Domus Books, 1981.

Europe during the oil crises of 1974 and 1979.[9] During the late 1980s, a resurgence of the environmental movement, sparked especially by concerns over global warming, reignited interest in the EV. Although the environmental movement has wanned somewhat in the 1990s, California's ZEV mandate has once again peaked interest in EV technology.

Impediments to a New Technological Trajectory

What has prevented the diffusion on EV technology, especially in light of the profound solutions it offers to the environmental quandary? The following is an examination of the factors that have inhibited this `green' technological trajectory.

Costs to Industry and Profitability

Monetary costs and concerns over profitability are a central impediment to any `green' technology. Although macroeconomic trends suggest that pollution control need not be economically problematic, initial capital outlay for environmental technologies remains an obstacle for some industrial sectors.[10] Kemp and Soete (1992) claim that economic uncertainties extend beyond initial capital outlay to include broader economic concerns:

> "Many firms...will be reluctant to adopt cleaner techniques because of the economic risks involved. Production routines and procedures have to be changed and employees have to learn and become familiar with the new technology.[11]"

Ultimately, industry concerns boil down to a question of profitability.

Such consternation over economic risk, has been a major impediment to the adoption of EV technology by automakers. Automobile manufacturers argue that each EV will cost an extra $10,000 to $20,000 US above what a comparable ICEV would cost.[12] They contend that such a cost would greatly reduce demand for their product. Moreover, automakers might be forced to take a loss on EVs and

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[9] International Energy Agency, 1993, pp.20-21.

[10] OECD, "The Technology/Economy Programme, Technology and the Economy: The Key Relationship, ch.9, 1992, pp.203-205.

[11] Kemp and Soete, 1992, p.451.

[12] Daniel Sperling, Future Drive: Electric Vehicles and Sustainable Transportation, Island Press, Washington D.C., 1995, p.138.

compensate for this loss by raising the price on ICEVs.[13] Sperling (1989) argues that initial costs for EVs conceal the fact that EVs will actually save the consumer money if full "life-cycle costs" are considered. Moreover, mass production of EVs is likely to reduce the costs significantly due to economies of scale. Nonetheless, the cost impediment for automakers is not easy to circumvent.

Appropriability Conditions

Related to the issue of costs and profitability, is the issue of appropriability conditions. Kemp and Soete (1992) site appropriability conditions as a significant determinant in the decision to generate clean technologies. Appropriability conditions refer to "the means through which a firm can reap returns from its innovations, and hold off other firms from eating too much into these returns.[14] Appropriability conditions are influential because a firm will not undergo the financial risks of developing a `green' technology if they cannot reap the benefits.

There is some evidence to suggest that the major automakers' apprehension over appropriability conditions has delayed the diffusion of EV technology. Schiffer (1994), claims that a patent-sharing agreement instituted in 1914 by the National Automobile Chamber of Commerce, has stunted technological innovations for the past 100 years, because automakers "knew that what they invented in one year could be industrywide practice by the next."[15] Investing in new technologies did not pay because a company could gain no more than a temporary advantage over their competitors.

More recently, the 1991 creation of the United States Advance Battery Consortium (USABC), a joint business-government R&D effort, has come with certain stipulations regarding patent rights:

> "Battery manufacturers who want [the USABC's] money must agree to ...relinquish patent rights to any innovation they make under contract. The [Department of the Environment] has largely ignored cries that this stipulation...flouts a federal law requiring the government to favour small companies over giants in such matters....[16]

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[13] BusinessWeek, "Electric Cars: Will they Work? And Who will Buy Them?, May 30, 1994, p.111.

[14] Kemp and Soete, 1992, p.449.

[15] Michael Brian Schiffer, 1994, p.171.

[16] The Economist, "The Electric Car's Achilles'

Kemp and Soete (1992) note that government action of this sort in not uncommon with respect to environmental technologies: "In view of the public interest in rapid diffusion of clean technology, there is probably more government willingness to limit appropriation than in the case of `normal' technology.[17]"Although far from conclusive, the government endorsed stipulations, regarding the USABC, are an indication of the automaker's anxiety over appropriability.

Technological Opportunities and Feasibility

Intimately tied to the issue of costs, profitability, and appropriability conditions, is the question of technological opportunities and feasibility. Following Dosi (1977), Kemp and Soete (1992) specify technological opportunities as a determinant of the decision to generate a clean technology: "As in the case of `normal' technology, these opportunities depend on accumulated scientific knowledge, available equipment and capabilities in organizations.[18]" While technological opportunity is a measure of `technical achievability', technological feasibility also incorporates the issue of costs. A technology that is technically achievable, but is overly costly, is not technologically feasible. Both opportunity and feasibility are significant when examining the case of EVs.

As the historical account outlined above suggests, EVs have been the focus of much research for the last century. Although incremental improvements have been made over this time span, no breakthroughs have occurred, and the EV remains an inferior product to the ICEV in terms of driving range, speed, acceleration, and cost.[19] Sperling (1995), maintains that EVs have undergone major improvements in the last five years, in terms of the motor, power electronics, transmission, aerodynamics, tire friction, and other auxiliaries. For example:

> "...advances in power electronics have made possible alternating-current (ac) drives that are cheaper, easier to maintain, and more compact, reliable, efficient, and adaptable to regenerative braking than the direct-current (dc) systems used in

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Axle," September 19, 1992, p.101.

17 Kemp and Soete, 1992, p.449.

18 Kemp and Soete, 1992, p.448.

19 See Sperling, 1995, pp.46-55; see also Schiffer, pp.175-190.

virtually all [EVs] in the early 1990s.[20]

Charging devices, a major concern for EV proponents, have also seen major improvements in the last decade.[21] Schiffer (1994) concurs on the progress of the EV: "The upshot...is that electric vehicle technology has improved enough so that a viable car can be made today.[22]

By all accounts, however, batteries remain the `weak link' of the EV. Lead-acid batteries are likely to dominate the EV market well into the next decade, because of their relatively low cost and high reliability. Improvements to lead-acid batteries are also continuing, and are likely to be significantly advanced by 1998.[23] Nevertheless, lead-acid batteries remain a questionable technological alternative in comparison to the ICE. Using lead-acid batteries, EVs will have a maximum driving range of 70 miles, and far less acceleration and power than the ICEV. Even the more promising battery technologies of the near future, such as nickel metal hydrade, zinc bromide, and zinc air, are inferior in performance to the ICE: "All chemical batteries that might be mass produced in the next decade seem likely to suffer from limited range, feeble acceleration, expensive replacement every three to five years and difficulties over recycling and disposal.[24]" The technological opportunity clearly exists, but relative to the ICEV, it not difficult to see why automakers are hesitant to produce EVs, and consumers are reluctant to endorse them.

When costs are taken into consideration, the technological feasibility of EVs is also called into question. While current lead-acid batteries are relatively inexpensive, they require replacement every 20,000 miles.[25] Future technologies do not fare much better. Nickel-Metal Hydride, one of the more promising alternatives in terms of performance, is currently priced beyond market reach.

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[20] Sperling, 1995, p.47.

[21] <u>BusinessWeek</u>, May 30, 1994, p.105.

[22] Schiffer, 1994, p.174; see also Freund and Martin, 1993, p.148.

[23] <u>BusinessWeek</u>, May 30, p.107; see also <u>CQ Researcher</u>, "Electric Cars," July 1993, p.580.

[24] <u>The Economist</u>, September 19, 1992, p.101.

[25] Sperling, 1995, p.48; see also Gordon, 1991, pp.95-98.

Research and Development

While technological opportunities and feasibility have been substantial impediments to the adoption of EVs, there is evidence to suggest that the deficiency in technological advancement is due to a lack of R&D.

The notion that research and development can be a significant factor in determining whether or not `green' technologies are adopted is widely recognized.[26] It is not only essential that R&D for `green' technologies take place, but that the funds be properly earmarked as well.

Sperling (1995) argues that EV technology has been largely ignored ever since the ICEV became the auto of choice in the US:

> "It's no surprise that today's electric vehicles cost more and perform worse than their gasoline counterparts. Gasoline cars have benefited from a century of intensive development; electric cars have been virtually ignored for over seventy-five years. Even today, gasoline cars profit from billions of dollars of research every year while electric vehicles receive a tiny fraction of that."[27]

Prior to California's ZEV mandate, less than $10 million a year was being spent on battery research aimed specifically at the vehicle market, "and most of that went to improving the primitive techniques employed in building battery packs for golf carts and slow-speed industrial vehicles."[28] James Womack, director of MIT's International Motor Vehicle Program, claims that R&D funds issued to automakers between 1969 and 1991, and aimed at alternative concepts such as EVs, were "a complete and total waste," because "the industry had no real interest in these ideas; they just took the money."[29] Jacoby and Steinbruner (1973), note that this lack of R&D is not surprising, given that the focus of automaker laboratories has been on qualities the market tends to value - speed, acceleration, fuel economy, and smooth and reliable performance: "It has never been concerned with developing advance technologies for the purpose of controlling emissions."[30]

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[26] See for example, OECD, 1992, pp.194-198.

[27] Sperling, 1995, p.36.

[28] Sperling, 1995, p.49.

[29] Nadis and MacKenzie, 1993, p.163.

[30] Jacoby and Steinbruner, Clearing the Air: Federal Policy on Emissions Control, Ballinger

Although it is somewhat speculative to assume that EV technology would have advanced dramatically had more R&D occurred, the case is strengthened considerably when one considers the advancements that have taken place since automakers learned that California law would soon force them into mass-producing EVs. In direct response to California's ZEV mandate, the USABC was launched in 1991. With funding provided by the federal government (50 percent), the Big Three (23 percent), battery companies (20 percent), and electric utilities (7 percent), USABC has an R&D budget of $230 million to be spent by 1995 and $100 million more per year into the early years of the next century.[31] Similar battery consortia were also formed in Japan and Europe after the creation of USABC. These R&D projects have paid off handsomely for EV technology. For example, nickel-metal-hydrade and lithium-based battery technologies have advanced steadily. This technological progression was duly noted by the California Air Resources Board (CARB), who responded after three months of public debate and a two-day hearing in Los Angeles in May of 1994, in which Ford voiced their opposition to the ZEV mandate:

> "We heard from no one who claimed the mandate had not accomplished its stated objective of stimulating technological development and innovation. While [EV] and battery technology may not have advanced much between the turn of the century and the 1980s, there is no doubt that tremendous advancements have occurred since we adopted the [ZEV mandate]. We heard over and over again that the mandate caused or contributed to these advancements."[32]

As noted above, the allocation and use of funds is also an important factor. While the ZEV mandate incited substantial R&D, Sperling (1995) argues that the central goal, of the USABC and the Japanese MITI consortium, is the development of a battery that would allow EVs to compete head-to-head with ICEVs. `The Economist' notes that USABC research and development is limited to "medium- and long-term work on batteries," to the exclusion of research on current lead-acid technology.[33] This emphasis on high power batteries has diminished R&D on low

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Publishing Company, Cambridge, Mass., 1973, p.52. See also Business Week, May 30, 1994, p.110.

31 Sperling, 1995, p.49.

32 Sperling, 1995, pp.40-41.

33 The Economist, September 19, 1992, p.101.

cost batteries, a factor which has delayed the introduction of competitively priced EVs.

Consumer Resistance

Kemp and Soete (1992), assert that the decision, on the part of industry, to generate a clean technology is determined in part by the potential market demand. The market demand, in turn, depends in part on the willingness of consumers to change their attitudes and modify social norms. Because consumers appear as diffuse sources of pollution, it is not always possible for government regulations to directly influence behaviour. Consumer acceptance of `green' technologies, therefore, relies heavily upon structural social change.

The environmental movement of the 1970s and 1980s represents a structural social change. While heightened societal consciousness of environmental issues has paved the way for California's ZEV mandate, however, Sperling (1995) cautions that consumers require more than an ecological justification for purchasing EVs. Detracting from the attractiveness of environmentally-sound EVs, is the fact that consumers have not been able to overcome some ingrained misperceptions, and some very real concerns about the EV. A number of surveys quantify consumer resistance to the EV. Of the 4,512 respondents to a recent study, for example, 36 percent said they "would definitely not consider purchasing an EV," and another 36 percent indicated they "would probably not consider an EV for their next automobile purchase.[34]" A 1990 survey by the Ford Motor Co. found that only 1 percent of the American population would buy EVs.[35] The history of the EV, reveals the difficulties in attempting to change consumer perception of the automobile's function. The ICEV won out over the EV in the early 1900s, because consumers were enamoured with the concept of `touring'.[36] This perception remains a near intractable quandary for the EV in the 1990s: "The crisis before us is largely cultural and perceptual; we may simply have to change our image of what a car looks like and does.[37]" John R. Dabels,

[34] CQ Researcher, July 1993, p.583. Note that 19 percent of the remainder of respondents were lukewarm to the idea of EVs, while only 6 percent indicated that they would definitely consider purchasing an EV.

[35] Sperling, 1995, p.58.

[36] See Schiffer, 1994.

[37] Nadis and Mackenzie, 1993, p.91.

director of market development for GM Electric Vehicles, has recognized that acceptance of the EV has been hindered by the consumers' inability to overcome a widely held fallacy - that automobiles are used *primarily* for `touring':

> "A common misconception among drivers is that they drive for long distances at a time. Our research shows that 84 percent of the drivers studied drove less than 75 miles a day, a total daily mileage well within the range of an electric vehicle.[38]"

EV endorsement has not only suffered because of a misperception of travelling distance, but also because of a misperception of travelling speed. The US Federal Highway Administration estimates that the typical home-to-work commute takes place at an average speed of 31 mph, far below the average speeds associated with `touring'.[39]

Schiffer (1994) cautions that the single most important lesson that the history of the early electric vehicle has to offer, is that the choice of a car technology is influenced by the *extreme*, not the average, anticipated use:

> "Middle-class Americans in the teens flocked to the gasoline car, even though [EVs] could meet all of their urban transportation needs, because they anticipated touring every once in a while. In the showroom, today and tomorrow, ordinary Americans will not be thinking about the 20-mile trek back and forth to work each day, but about the few uncommon occasions...when an extra-long range is essential.[40]

Misperceptions over driving habits explains only part of the consumer resistance to EVs. Drivers have also expressed legitimate concerns over price, quality, safety, and infrastructural requirements.[41] For example, a recent survey found that consumers were willing to pay a median price of $14,200 (US) for an EV, far below the projected $25,000 for GMs two-seat Impact.[42] Concerns over

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38 CQ Researcher, July 1993, p.581.

39 Nadis and MacKenzie, 1993, p.75.

40 Schiffer, 1994, p.187.

41 Laurie Michaelis, "The Abatement of Air Pollution from Motor Vehicles," Journal of Transport Economics and Policy January 1995, p.81. See also, Freund and Martin, 1993, pp.148, 175.

42 CQ Researcher, July 1993, p.583.

the necessity of `home-recharging' has also thwarted consumer acceptance of the EV.[43] Regardless of the origin of the misperceptions and concerns, it is evident that consumer resistance has helped thwart the diffusion of EV technology.

Factors with Mixed Evidence

All of the factors discussed above have been decisive obstacles to the diffusion of EV technology. The literature on environmental technological trajectories also contains some factors in which the evidence is less clear-cut.

Mode of Regulation

North America's rightward shift in politics during the 1980s and 1990s reignited a long-standing debate pertaining to regulations and markets. This debate has manifested itself in the realm of environmental regulation, pitting those in favour of the traditional command-and-control (CAC) approach to regulation against those who prefer the harnessing of market forces.

Analysts focusing on environmental technologies, have joined the fray. A reliance on CAC regulation has been pointed to as a prime impediment to technological innovation. Critics argue that a CAC approach, with its rigidities and emphasis on `best-available-technology', stymies the incentive for producers to reduce pollution beyond the required level, and impedes both the production and diffusion of innovative pollution-reducing techniques.

The evidence concerning EVs is mixed. Sperling (1995) contends that US regulations for automobiles are "fundamentally flawed", because they focus only on `downstream' tailpipe emissions, whereas the emissions from EVs will largely be `upstream' - from electricity-producing plants. Moreover, Sperling emphasizes the automakers' fear that any technological innovation will be used against them: "that those specific improvements will be either explicitly required by regulators or used as justification for further tightening of standards.[44]"

Although the evidence suggests that a reliance on the CAC approach to regulation hindered EV technology, a great deal of this evidence is conjectured. What is not speculative, is that the 1990 California zero emission vehicle (ZEV) mandate, a mandate drawn up within a CAC framework, has been the catalyst for the diffusion of EV technology: "Thanks largely to California's pending zero emissions deadline, which has been adopted by several other states, the nation's EV population is due to explode by the end of the decade.[45]" Even Sperling, a

[43] CQ Researcher, July 1993, p.585.

[44] Sperling, 1995, pp.118-119.

[45] CQ Researcher, July 1993, p.592.

proponent of regulatory reform, recognizes the power of the CAC approach in the case of EVs:

> "No imaginable set of incentives and subsidies could ever have achieved in such a short time what the ZEV mandate has achieved...Almost entirely because of the mandate, every major automaker in the world has now invested in electric vehicle development."[46]

Market Structure

Another factor that can have an important effect upon the diffusion of an environmental technology, is market structure. Kemp and Soete (1990), profess that "the diffusion of pollution abatement technology depends on the market structure of the `polluting' sector."[47]

The evidence regarding EVs is mixed. The market structure of the automobile industry has evolved significantly since Jacoby and Steinbruner remarked in 1973 that the classic oligopolistic nature of the auto industry facilitates "tacit arrangements" between firms to limit competition.[48] Limited competition between World War Two and the mid-1970s, discouraged automakers from taking the lead in introducing major technological or design changes. With the emergence of Japanese companies in the late 1970s, however, competition intensified. General Motor's ambitious `Impact' EV program in the early 1990s reflects this competition, and indicates an elevated willingness on the part of automakers "to innovate and take risks in pursuing promising new technologies."[49]

While competition in the auto sector has escalated in the last two decades, there is reason to suspect that the market structure has remained aligned in such a fashion that has impeded EV technology. An attestation to this assertion is the inability and reluctance of small EV companies to expand their market share. Solar Electric Engineering, Sebring Auto-Cycle, and Solar Car Corporation, for example, are EV companies that have struggled to survive under the shadows of the major

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46 Sperling, 1995, pp.135, 140.

47 Kemp and Soete, "Inside the `Green Box': on the economics of technological change and the environment," in New Explorations in the Economics of Technological Change 1990, p.253.

48 Jacoby and Steinbruner, 1973, p.53.

49 Sperling, 1995, p.133.

automakers. These companies and others like them, will be "shoved further into the background as the leviathans of the auto industry belatedly introduce EVs, later in the 1990s."[50] Rather than challenge the major automakers, these companies have to satisfy themselves with co-operating with the automotive behemoths. A vice-president from the EV company U.S. Elictricar, summed up this sentiment: "When you're dancing with the giants, you do anything wrong and they'll crush your toes."[51]

Clusters of Technological Trajectories

Kemp and Soete (1992) note that economic growth is likely to be characterized by clusters of economically interrelated technological trajectories. These technologies reinforce one another, and facilitate `locked-in' development.

The evidence concerning EVs is once again mixed. The ICEV has evolved hand-in-hand with moderately priced and adequately abundant oil-based energy.[52] Nevertheless, the fuel that would energize EVs - electricity, has also been relatively inexpensive and in abundant supply for nearly three-quarters of a century. Furthermore, evidence from independent researchers as well as private and public institutions suggest that there is no need to build new electricity capacity to support large numbers of EVs.[53]

While the availability of electricity may not have been an impediment to the diffusion of EV technology, the infrastructural requirements for this energy source have provided a barrier. Although Sperling (1995) maintains that EVs would not require a new fuel distribution network, others disagree. Auto industry analyst Maryanne Keller, for example, asserts: "For electric power to become anything more than an automotive oddity, we will need convenient recharging stations along the road...but we don't have that infrastructure at this point."[54]

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[50] Schiffer, 1994, p.178.

[51] BusinessWeek, May 30, 1994, p.114.

[52] The exception is of course the oil shortages during the 1970s. Not surprisingly, alternative fuels gained cogency during this era.

[53] Sperling, 1995, pp.58, 64; see also CQ Researcher, July 1993, pp.584-585.

[54] CQ Researcher, July 1993, p.585.

Conclusions and Policy Implications

The findings suggest that no single answer can fully explain the failure for the dispersion of EV technology. The `conspiracy theory' does not account for many factors, such as the costs to industry, and consumer resistance. Similarly, the `consumerist theory' neglects the impact of appropriability conditions. The `technological constraint' theory probably offers the single most robust explanation; but it too neglects important factors such as the mode of regulation. Policy-makers focusing on EV technology, must recognize the multitude of impediments in order to deal effectively with the issue.

The material contained in this paper, is part of a larger debate pertaining to the role of technology and the environment, and has implications that extend beyond the case of the EV. This debate has its roots in an historical dialectic between `pessimists' - `founded' by the reverend Thomas Malthus, and `optimists' - inspired by classical economists such as Adam Smith. The contemporary polemic pits Neo-Malthusians such as Elrich (1968, 1990) and Meadows et. al. (1972), against the neo-classical economists such as Cole et al. (1973), Simon (1981), and Rosenberg (1994).

As a central point of contention between these two sides revolves around the role of technology, the debate has manifested itself in literature regarding the political economy of technological change. The rift between the positions of Heilbroner (1974) and Onuf (1984), and that of Freeman (1992), is illustrative of how the debate has manifested itself in this realm. While the latter two authors have a pessimistic/neo-Malthusian outlook, a central point in Freeman's thesis is that changes in technoeconomic paradigms, which are a major feature of Schumpeterian long waves, possess the capacity for positively altering the relationship between humans and the environment.

The findings of this paper sound a note of caution to the optimist camp. The failure of the EV innovation to become widely dispersed suggests that technological trajectories are not "an autonomous force with their own internal trajectory" (kemp and Soete, 1992), and `green' technoeconomic paradigms do not necessarily accompany the crest of a long wave. EV technology has been existent for over a century, consistently failing to solidify its position in society, despite numerous opportunities throughout the last century. Concern over the environment, the most recent and perhaps most pronounced opportunity for the diffusion of EV technology, has once again met with great resistance, California's ZEV mandate notwithstanding. The failure for the diffusion of EV technology indicates that policy-makers, interested in promoting `green' technologies, will have to focus their attention on the larger socio-political framework in which environmental technological trajectories are nurtured.

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