

The Path Dependent Road to Sustainable Personal Transport

Increasing returns economics and the lock-in and lock-out effects on the history and future of motorized transport

Introduction & Research Questions

While other economic sectors have begun to decarbonize following the international resolve to combat anthropogenic climate change, carbon emissions from transportation have actually been increasing in recent decades. Economic growth is the simple two-word explanation for this fact, as globalization of trade has had a double-edged impact on transportation demand. A global market is made possible only by increased transport volume, and the prosperity it has generated for a greater share of the population has generated a larger market for personal vehicles. However, this fails to explain why the carbon intensity of modern transport modes has remained so high. An absurd 93% of worldwide transport is fueled by oil, meaning it is the economic sector that remains most monopolized by fossil fuels today. This trend runs counter to logic, as there are numerous reasons throughout automotive history which should have moved the market away from fossil dependency much more quickly than other sectors.

First of all, electric vehicles (EVs) and biofuels have been in existence for almost two centuries as alternatives to petrol cars, much longer than renewable electricity or nuclear power, for example, which are both serving to displace thermal power. Second, the security risks and price volatility characteristic of a cartel-dominated global market were starkly demonstrated by the oil shocks of the 1970s. Third, worldwide concerns over air pollution and its health effects have largely been attributed to the decentralized nature of transport emissions. Fourth, the widely assumed technical superiority of gasoline cars is a frequently disproven misconception by nearly every performance measure. Fifth, as with all extractive fuel industries, the finite nature of the resource dictates that the transition away from oil is inevitable. Despite all these rational motivations and the additional impetus of environmental sustainability against climate change, the global reliance on oil has actually increased by 67% since the oil embargo of 1973.

The first objective of this thesis is to explore how the oil-powered vehicle has been - and continues to be - able to enjoy such market dominance by examining the history of the automotive industry through an institutional lens. A theoretical framework incorporating path dependency, increasing returns economics, techno-institutional lock-in and lock-out, and systems of innovation theory provides a clear political economy perspective of the current state of affairs of personal transportation systems, how it arose, and why there exists such profound inertia against change. The analysis is focused on the United States and Europe, and the second objective of the dissertation is to compare the modern institutions which have developed around transportation in these two societies which pioneered motor vehicles. This also considers the different political contexts in the sector between the two governments and attempts to evaluate the existing policies for sustainable transport transition. The third objective is then to use this collection of insights to inform legislative strategies for a sustainable transport future.

Three research questions direct the narrative of my thesis, and they are addressed throughout the body but then more directly in the conclusion. First, what are the major barriers to the decarbonization of transport in the EU and the US, and what are the exploitable motivations? Second, what insights can be gained from a path dependency perspective of automotive history for policy making and to what extent have they been acknowledged by either government? Third, what would a sustainable transportation

sector look like ideally in either region and how should they each shape their short-term, medium-term and long-term visions? On a global scale, the US and the EU are both Western capitalist democracies. but the manifold differences beneath the surface provide fertile ground for intricate analyses into the true nature of our oil dependency and what approach or approaches should be taken to break it.

Theoretical Framework

Path dependency theory is founded in the simple assertion that history matters, but when applied to economics this becomes a complex and controversial idea because it questions the widely accepted neoclassical notion that a liberalized market is omnipotent in returning the singular most efficient economic equilibrium. Instead, path dependency emphasizes the importance of initial conditions - historical and institutional circumstances - in determining market outcomes, such that the most optimal of the multiple possible equilibria does not always win. While it may appear obvious that gasoline engines are simply the best technology available for personal transport, path dependency suggests that in reality there may have been any number of random, seemingly insignificant events which led society to choose this technology over the competitors. Note that while these theories are most easily described in terms of technological development, they can also be applied across the realm of social sciences.

Increasing returns economics describes processes parallel to path dependency by which a winner is often determined early in the development of a new market. Not only is the competition sensitive to those forces external to the market, but also to business strategies by which a particular technology can gain an advantage over the alternatives. Four specific mechanisms can drive increasing returns, and oftentimes the first technology to exploit one of them is soon able to benefit from the others and establish a positive feedback loop leading to its market dominance. First, *economies of scale* produce greater returns simply by increasing output volume for those who can afford the initial setup costs. The second is *learning effects*, which describes the industry's ability to develop expertise and adapt to consumer preference. Third, *network effects* is a broad concept which means that the product's value to its users increases as its level of pervasiveness increases in society. Finally, *adaptive expectations* produces increasing returns for a technology when consumers and producers adapt behaviors to the new expectation that its dominance will persist.

The dominant design theory states that there is a human tendency to establish a universal standard in knowledge-intensive and highly networked sectors for the sake of simplicity. This desire can accelerate and intensify the effects of path dependency and increasing returns on the market and lead to the lock-in effect, when the cost of switching to a superior alternative becomes greater than the benefit. This lock-in of the dominant design deepens as infrastructure is built to support it, co-developed industries depend on it, societal and political institutions coevolve with it, and behavioral institutions arise around it. Together, these form a techno-institutional complex (TIC) that becomes entrenched within society.

A TIC can hold great power in the political economy, to the extent that it locks out all alternatives in its sector(s) from the market. My analysis of this techno-institutional lock-out indicates that there are two distinct classifications of this phenomenon: *inherent lock-out* and *intentional lock-out*. The former is a set of existing institutions which dictate rational behaviors and naturally oppose a diversified market, such as investor preference for the dominant design and the lack of education for alternative technologies. The latter describes concerted efforts by leaders of the TIC to create new institutions specifically for the purpose of suppressing competition, accomplished through lobbying, private organization and network coordination, media influence, and market manipulation.

History of the Transportation Techno-Institutional Complex (TTIC)

When the first internal combustion engine (ICE) was invented in 1826, the petrol engine car was by no means destined to be the future of transport. In fact, oil was not discovered until 33 years later, and this prototype was actually designed to run on ethanol. As personal automotion began to grow, in 1900 ICEs were the least popular choice with only 22% market share compared to 40% steam engines and 38% EVs. This would completely change in 1908 when Ford introduced mass production to the automotive industry with the Model T, significantly reducing their costs. At that time, EVs were easier to drive, pollution free and held the world records for speed and range, so the only advantage of ICEs was their price. The Standard Oil monopoly then began to construct a vast network of gas stations so that range was no longer an issue for ICEs by 1920, and the US government began expanding the road infrastructure to support long distance driving. Clearly, business strategy combined with coincidental timing and techno-institutional coevolution imparted increasing returns to scale and by network effects on the ICE, enabling the technically inferior vehicle to become the dominant design. EVs disappeared from roads by 1930, at which point 80% of the global car market was controlled by the 'big three' of Ford, GM and Chrysler. This oligopoly ensured that they would attract the top talent in the labor market and that no investment capital in the sector would be available for alternative technologies, perpetuating the lock-out.

The dominance of gasoline for fueling the ICE was similarly determined by path dependence. Just three years after the oil was struck in 1859, the US introduced a heavy 'sin tax' to fund the Civil War on all alcohol products, including fuel ethanol. This serendipitous historical circumstance caused the ICE to become popularized as a petrol-burning engine, although the Model T and many other early cars were actually flex-fuel vehicles (FFVs) fully capable of handling pure ethanol. The auto industry was wise to establish a network economy with both fuels, especially since oil was thought to be a very scarce resource and since ethanol was better for horsepower, better for air quality, and better for the engine as pure gasoline without an octane boosting agent actually produced a harmful 'knocking' effect on engines. Gasoline's only edge was that it offered better fuel efficiency and thus was significantly cheaper. Moreover, Standard Oil's business strategy of consolidating 90% of US refined oil allowed them to capture increasing returns to scale and to control prices to lock out ethanol even after the sin tax was lifted in 1908. Meanwhile in Europe, ethanol was widely blended into petrol as an octane booster, and everyone from farmers to scientists to carmakers in the US also supported the 'gasohol' movement.

Moreover, the auto industry reversed its position on gasohol in 1924 when GM unveiled leaded gasoline, which had the same performance and price as gasohol, the disadvantage of disastrous effects on public health, and the distinct advantage of patentability. Standard Oil of New Jersey (now ExxonMobil) teamed up with GM to form Ethyl Gasoline Corporation, the sole producer of leaded gasoline, and this insidious partnership solidified the TTIC around gasoline-powered ICEs. The TTIC also included the mighty American Petroleum Institute (API), and it was able to coordinate the intentional lock-out of gasohol using its deep finances, socially perceived prestige and vast networks to influence politics, spread misinformation and refuse distribution licenses to sellers of gasohol. Leaded gasoline commanded a 90% market share in the US by 1936, and would later achieve similar dominance in Europe as WWII and the Marshall Plan increased petroleum imports from the US. Once again, a market outcome was determined by historical events and unsavory business practices instead of technical performance and public interest.

The TTIC was strong enough to even override national energy security concerns. European nations with effectively zero oil reserves had established fiscal support for ethanol production during the

interwar period, but these would be cancelled in favor of cheap leaded gas. In the US, propaganda and lobbying from the API delayed any biofuels legislation until almost two years after the second oil crisis of 1979, even as the TTIC was weakened after GM and Exxon suddenly sold Ethyl Corp in 1962. The US anti-air pollution social movement of the 1960s led to a court order for all new cars to have catalytic converters, which are by pure coincidence incompatible with leaded gasoline. This caused a divergence of interests for the oil and car industries, and for once historical circumstance and collective action turned path dependence against the TTIC. The 40-year lock-out of EVs was temporarily ended when the US legislated a 5-year public funding program for EV research in 1976, and the 60-year lock-in of leaded gas was ended when it became completely phased out in 1986. The oil industry then created new octane boosters to continue the lock-out of gasohol until ethanol blending was finally mandated by US Congress in 2005 and by EU Parliament in 2003, citing energy security and climate change as motivations.

Modern Transportation Institutions in the US and the EU

As a relatively young, sprawling nation priding itself upon innovation, individualism, freedom and economic prosperity, American society readily molded its culture around the motor vehicle. Today, the US is characterized by the most vehicles per capita in the world, the lowest average fuel efficiency in the world, the largest average vehicle size next to Canada, and the highest oil subsidies and lowest gasoline prices of any advanced economy. The TTIC is of course the driving force behind this caricature of a transport sector which consumes the most gasoline per capita in the world (439 gallons annually per capita, or 143.37 billion gallons total in 2017), and its lobbying power and societal influence has been growing ever stronger. Just the API and Exxon Mobil combined to spend \$92 million on obstructive climate lobbying in 2015, and this doesn't include the undisclosed sums they channel to SuperPACs and to anti-climate think tanks and 'astroturf' organizations inciting fake grassroots movements against climate policies. The total annual expenditure in just the US is thought to be somewhere around \$500 million, while only \$5 million was spent on climate action lobbying across the world in 2015, so it is in most US politicians' rational self interest to preserve the techno-institutional lock-in of oil.

However, the 2005 Renewable Fuel Standard (RFS) mandating gasohol has become an institution such that currently almost all gasoline sold is a 10% ethanol blend (E10), and the ethanol target for 2022 would represent 25% of all transport fuel. This would represent a true destabilization of the TTIC, but a new obstacle now exists because conventional crop-based ethanol has reached its mandated production limit of 15 billion gallons, and advanced biofuels from cellulosic biomass, waste and algae remain well below their initially projected output. Further legislative action will likely be necessary to support their techno-economic development for market readiness, and this will have to compete once again with the inherent and intentional lock-out forces ever more pervasive under the Trump administration.

European transport institutions evolved very differently from the US, affected mostly by the lack of domestic oil, older infrastructure which was not designed around motor vehicles like in the US, and shorter travel distances since local economies are more institutionalized, cities are spaced closer together, and open borders were not instituted until 1985. Car ownership rates today are about 27% lower than the US; the vehicle fleet is the most fuel efficient in the world; average car size is much smaller than the US; scooters, bicycles, public transit and trains are better integrated in society; oil is subsidized at the lowest rate in the world; and petrol prices are among the highest in the world. In total, the EU consumed 85.12 billion gallons of gasoline and diesel in 2015 (165.3 gallons per capita), about 70% lower than the US.

The EU, from its leadership to its citizenry, has also exhibited a strong sensitivity to the international effort against climate change, so lock-out forces from the TTIC are not as effective as in the US.

However, some of the EU's well-intentioned policy objectives have backfired and may actually serve to propagate inherent lock-out mechanisms. First, the very high fuel economy standards set by the Commission have led to an increase in diesel engine cars which are more efficient by nature but also emit more NO_x, indirectly leading to "VW diesel-gate." Moreover, life cycle assessments (LCA) of biodiesel declare it much less sustainable than advanced biofuels (ethanol), and diesel car owners will be locked out from that market. As for the biofuels market, while investors seek to minimize uncertainty above all else, biofuels policy in the EU has been defined by constant change. Conventional biofuels have grown to a 6% market share in the past 14 years, but the EU Parliament now plans to phase them out due to sustainability concerns over indirect land use change (ILUC). Meanwhile, sustainability criteria on advanced biofuels have grown more stringent three times in the past seven years, and only 4 member states are projected to reach the 2020 target of a 10% share of renewables in transport amidst this confusion.

Conclusion and Policy Implications

My research has concluded that the neo-institutionalist forces of path dependency and increasing returns have had at least as large of an impact as techno-economic factors on the evolution of the modern personal transport system. The almost century-long absolute lock-out of biofuels and EVs has been broken, but it stunted their development and distorted the market so that they cannot compete without policy support today. Legislators in both the US and the EU have begun to address inherent lock-out through tax incentives for EV sales, financial support for biofuels R&D, and ethanol blending mandates. However, the impact on transport decarbonization has been minimal thus far, and the approach moving forward must focus on developing TICs around the technologies to compete with the incumbent TTIC.

First, public investments in infrastructure will be necessary, especially EV charging stations. This is best viewed as a medium term goal, as R&D will improve charging speed and further decarbonization of grids will improve the sustainability of EVs. Second, scholarships or funding for education and training programs would build capacity and address the workforce lock-out. Third, the absorptive capacity for both technologies must be increased to enable them to capture a larger market share. The most efficient solution for this would be to transition the vehicle fleet to flex-fuel plug-in hybrid electric vehicles (FFPHEVs), which are capable of handling pure gasoline, pure ethanol, any gasohol blend, pure methanol and electricity. Major automakers such as Ford and Chevrolet have already developed FFPHEV models, and a policy mandating their production would be less costly for car companies than the EU fuel economy mandates. A flexible vehicle fleet would allow for a truly liberalized transport fuels market tradeable on the energy exchange, and also will enable governments to prioritize whichever fuel sources offer the best techno-economic and sustainability performance in their country while avoiding lock-in.

If path dependency can teach us anything about the future of technology development, it is that the short term matters most, and this holds particularly true in the face of climate change. While US lobby and fuel subsidization institutions need to be changed, intentional lock-out can be addressed most quickly by coordinating a powerful counter-lobby against the oil lobby and by subsidizing biofuels. While the EU is noble to pursue unequivocally sustainable policies, it is wiser in the short term to decrease the TTIC's market share as quickly as possible by delaying the crop ethanol phase out until advanced biofuels are more market-ready. Policy will determine whether sustainable transport will proceed with increasing returns or if it will stall yet again, and this time the EU is in a position to lead.