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Driving into a Paywall: The Subscriptionization of Consumer Vehicles

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Abstract

This paper examines subscriptions as a mechanism for transforming consumer-owned vehicles into technological assets that generate rents for automakers. Our concern is the contingencies of *how* and *under what circumstances* this assetization is unfolding. The paper's contributions are twofold. First, we analyze the sociotechnical and political-economic conditions that automakers are exploiting to transform consumer vehicles into rent-generating assets via subscription. These include governmental mandates and consumer demand for electric vehicles (EVs), and efforts to capitalize on limited advances in autonomous vehicle (AV) technology. Second, we argue that while the automotive industry has explored assetization, and even subscriptions, in the past, the paywalling of pre-installed functionalities is a distinct phenomenon likely to affect the wider ecology of automobility in ways that further entrench powerful and moneyed interests while undermining consumer welfare and the public good.

Keywords

subscriptions; financialization; automotive technology; automotive industry; assetization; political economy

Introduction

In July 2022, BMW started selling heated car seats by subscription in select markets. Although drivers in the US were not immediately affected, the news caused an uproar. Car enthusiasts railed against subscriptions in online forums, consumers lampooned the move on social media, and newspapers responded with incredulity (Bryant 2022; Westbrook 2022). The idea that individuals would have to pay in perpetuity for features installed on vehicles they already own—or for which they are making lease or loan payments—seemed to undermine the freedom and autonomy classically associated with automobility in the US and beyond (Miller 2001; Seiler 2008). Consumers were so bewildered and frustrated that BMW had to issue a statement walking back the reports and clarifying that existing vehicles would not lose functionality (Holderith 2022).

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In the automotive trade press, BMW's plans came as less of a shock. For years, analysts had anticipated the integration of subscription payments and onboard purchases in light-duty consumer vehicles (Berk 2021). In fact, BMW had already developed a reputation for stinginess by charging monthly fees for access to software-enabled services, such as Apple's CarPlay entertainment system, which Apple provides to automakers for free (Westbrook 2022). Nor is BMW alone in its ambitions to "disrupt" the auto trade with onboard subscriptions. Nearly every automotive original equipment manufacturer (OEM) is gearing up for, or already implementing, subscription fees for built-in functionalities. For an annual payment of $1,200 USD, Mercedes-Benz will "increase the torque and maximum output" of its electric vehicles (EVs) (Tucker 2022). Porsche charges monthly for EV range-optimization and lane-assist, Cadillac for hands-free driver assistance, Subaru for remote ignition, Audi for its Wi-Fi enabled navigation system, and Tesla for its persistently misnomered "Full Self-Driving" mode (Berk 2021; Lyons 2021). These and other onboard services are throttled by the OEM until car owners pay for over-the-air (OTA) updates to vehicle software and firmware—like a paywall, for your car.

The monetization of onboard vehicle features—what business scholar Anirudh Dhebar (2022) calls "preinstalled functionality-as-a-service"—follows a pattern of technological enclosure and "assetization" observed across economic sectors (Bernevega and Gekker 2022; Birch and Muniesa 2020; Langley 2020). Assetization describes the sociotechnical and legal processes by which things are constructed as revenue-generating property, or assets. Whereas profits from commodity production depend on sales, assets generate income without the transfer of property ownership—they produce *rents* rather than profits (Birch 2015, 122; Christophers 2020). This makes assetization integral to the accumulation strategies characteristic of "technoscientific capitalism," in which digital enclosure facilitates new forms of rent extraction (Birch 2020; Langley 2020; Langley and Leyshon 2017; Sadowski 2020).

We examine subscription as a mechanism for transforming consumer-owned vehicles into technological assets that generate rents for automakers—a process that we call "subscriptionization." We use subscriptionization to refer to a specific mode of assetization in the automotive sector because cars can be assetized in different ways (e.g., for a rental car agency or an Uber driver).[1] Our concern is the contingencies of *how* and *under what circumstances* subscriptionization is unfolding as a particular form of assetization. Like other "tethered devices," subscriptionized vehicles enclose select features, such that vehicular functionality remains under the control of manufacturers after a car has been sold (Hoofnagle et al. 2019, 785; Zittrain 2008). However, as we show, the subscriptionization of consumer vehicles is less about the "end of ownership" (Perzanowski and Schultz 2016) as much as a novel and insidious reconfiguration of the relationship between ownership, debt, and rentiership.

[1] See Lou (2022) for journalistic use of "subscriptionization."

Notably, the tethering and enclosure of vehicle functionalities via subscriptionization is not actually necessary to achieve the environmental benefits and safety advances that automakers invoke to justify their rent extraction. Automakers therefore face significant challenges convincing various stakeholders in the automotive ecosystem that subscriptionization is not only acceptable but desirable and valuable. We consider vehicle subscriptionization to be a contested frontier of accumulation, as automakers are presently struggling to reshape the culture, technologies, and economics of automobility to suit their own business preferences. For example, study after study has found a strong preference among prospective car buyers to not pay subscription fees (Cox Automotive 2021; LaReau 2023). Industry analysts are "skeptical" (Hawkins 2022), business scholars are dubious (Dhebar 2022), but automakers are proceeding despite the concerns. Several have projected that subscriptions will become a leading source of revenue growth in coming years (Stumpf 2022; Subramanian 2023). General Motors (GM) told investors that software fees will generate an additional $20–25 billion annually by 2030 (Marshall 2021). Stellantis, the multinational automotive manufacturing company that owns American OEMs Chrysler and Dodge, anticipates roughly the same (Holderith 2021). If the automakers are successful in their "paywalling" campaigns, these figures would represent about a 170 percent increase in earnings for GM. For Stellantis, they would be closer to 800 percent.[2]

The paper's contribution is twofold. First, we analyze the sociotechnical and political-economic conditions that automakers are exploiting to transform consumer vehicles into rent-generating assets via subscription. These include governmental mandates and consumer demand for vehicle electrification, and competition between the tech sector and automakers to capitalize on limited advances in autonomous vehicle (AV) technology. Second, we argue that while the automotive industry has explored assetization and even subscriptions in the past, the paywalling of pre-installed functionalities is a distinct phenomenon that affects not only consumers but also the wider ecology of automobility, including how cars are sold, repaired, and regulated.

In the next section, we discuss how automakers historically capitalized on consumer debt by extending credit to car buyers; this provides a point of comparison to the revenue generated by subscription and how consumers are likely to be affected by feature paywalls. Following that, we argue that automakers are seizing on pressures to increase environmental sustainability and automotive safety as excuses to impose fees on consumers. We then discuss the consequences of this rentiership for the wider ecology of the automotive sector, identifying critical areas for further research and regulation. We conclude by emphasizing that if it continues, subscriptionization is likely

[2] Calculations are based on GM and Stellantis' respective earnings for Q2 2022–Q1 2023, using the most conservative projections for subscription income. GM's net earnings were around $11.59 billion and Stellantis' were around $2.78 billion.

to generate technological, economic, and regulatory path dependencies in ways that will benefit corporations to the detriment of public safety and environmental sustainability.

Financial Vehicles

One might assume that automakers make most of their money manufacturing and selling automobiles. This is not true: automakers generate large portions—sometimes the majority of their earnings—from financial services. Once ancillary to car sales, financial divisions like Ford Motor Credit, Toyota Financial, and Nissan Motors Acceptance Company have subsidized the narrow profit margins of car manufacturing for decades (Borghi et al. 2013; do Carmo et al. 2019, 2020).

GM was the first automaker to establish a financial services division in 1919. After failing to raise a desired $50 million from stock offerings in a bid to compete with Ford, executives determined that public financing "needed to be juxtaposed with an internal system of capital appropriation arrangements" (Maielli and Haslam 2016, 6). Rather than raise capital by selling equity, GM issued millions in bonds to finance a first-in-kind lending subsidiary, General Motors Acceptance Company (GMAC). GMAC created a market for financing car purchases that increased demand for inventory, boosted the company's national footprint, and freed the corporation from dependency on the stock market at a time when banks and regulators viewed car ownership as a luxury (Calder 2001; Maielli and Haslam 2016). By 1940, GM's financial assets in outstanding loans and other receivables was equivalent to 127 percent of its manufacturing business (Maielli and Haslam 2016, 13).

The "financialization" of automotive firms continued over the following decades, but the trend accelerated in the 1980s after a wave of financial deregulations (Evanoff 1985; Lavoie 2012). Automakers first took advantage of these by expanding their financial products beyond car loans and drivers' insurance. GMAC issued mortgages in 1985 and Ford Motor Credit acquired First Nationwide to break into savings and residential loans (Lin and Tomaskovic-Devey 2013, 1293). The same year, GM and Chrysler issued the first financial securities backed by auto loans, leases, and other receivables (Rosenthal and Ocampo 1988, 107–188). In addition to provisioning capital to automakers at better rates than banks, the securitization of cash flows from OEMs' financial divisions created demand for a new market in asset-backed securities that would grow over the next decade to encompass nearly every conceivable form of recurring revenue—from credit card and student loan payments to computer leases, royalties, whole business loans, and more (Buchanan 2016, 80).[3]

Auto debt in the US has since ballooned, particularly in recent years (Davis and Shepard 2024). Between 2012 and 2022, total automotive debt doubled. Several factors contributed to this

[3] Securitization is a financial operation that pools financial assets and repackages them as interest-bearing securities through a "bankruptcy remote" entity. By satisfying underwriters' and regulators' concerns with risk and credit enhancement, securitization gave automakers access to a much larger pool of investors and potential capital (Buchanan 2016, 77–110).

spike, including public sector disinvestment, rising housing costs, wage stagnation, and price inflation, but many have also noted a dramatic uptick in subprime auto lending (Pollard et al. 2021; Walks 2018).[4] Over the same period, the total value of automotive-backed financial vehicles also doubled, with about 92 percent of all auto loans packaged into investable securities (St. Louis Fed 2025). And while the proportion of loans originated by automakers relative to third parties has fallen in recent years (Latham 2022), automakers still manage to raise impressive sums from securitization. In 2022 alone, Ford, Toyota, and GM raised $7.6 billion, $8.25 billion, and $12 billion, respectively, on securitized loans—and 2022 was a slow year (Pizzolato 2023).[5]

A New Capitalization Strategy

Automakers helped create a society of debt through their lending and financial services divisions (Calder 2001). The asset-backed securitization they pioneered contributed to the "financialization" of the wider economy by "shift[ing] debt from a concrete relationship with an entity . . . to an abstract connection to the financial markets" (Davis and Kim 2015, 208). Securitization makes debt a "lived abstraction" (Bryan, Martin, and Rafferty 2009). But debt is not the only revenue source that can be securitized (Leyshon and Thrift 2007), and the income that automakers plan to generate from onboard vehicle subscriptions will not replace the loans they are already originating and securitizing—it will be another source of revenue entirely, and a significant one at that. Some automakers project upwards of $15,000 USD per vehicle in subscription earnings (Hanley 2021).

Like loans, leases, and insurance, subscriptions produce positive cash flows that extend in time toward some horizon of futurity. To accountants, subscription payments are another receivable—a financial asset. Although none have announced plans to do so, automakers are likely to securitize subscription revenues the same way they do income from financial products. This is already happening in the tech sector, where investors have discovered that subscription contracts for software-as-a-service products can be aggregated and sold as securities just as easily as debt (Danco 2020; Luttig 2020). As a tech-finance insider puts it,

> . . . it is underappreciated by many technologists how many technology companies are, often quietly, building vehicles which have cash flow profiles similar to asset backed securities" (see figure 1).

[4] Despite the role of subprime loans in the mortgage securities crisis and global financial meltdown that followed, subprime lending has become more prevalent in the auto loan industry (Felton 2022; Romero 2017). Roughly half the loans originated by automakers' financial divisions in recent years are subprime (Latham 2022).

[5] Securitization data was calculated using figures from *Auto Finance News* (2023).

Figure 1. Screenshot of Patrick McKenzie (@patio11)'s social media comment, (2020). Source: Social media platform, X.

Fintech startups like Pipe are seizing on this insight by providing exchanges where investors can bid on subscription-backed securities (Kruppa 2021). Investors and money managers increasingly view subscription as an exciting new investment class with distinct advantages over other "esoteric" assets (Zhang 2022).[6] And although exchanges like Pipe presently cater to tech companies seeking early-stage funding, the capital their clients are attracting from blue-chip investment banks and sovereign wealth funds is likely to tempt larger incumbents, including automakers, to the exchanges.

But if subscriptions resemble financial products on corporate books, they also differ in important ways. Whereas securitized debt configures loans as financial assets, subscriptions to onboard vehicle features turn cars themselves into assets (Birch and Muniesa 2020). Loans generate positive cash flows for lenders in the form of interest on the principal. This interest is a form of rent since cash is a scarce resource that lenders control and to which they charge for access (Christophers 2020). With subscriptions, subscribers pay recurring fees for access to functionalities that OEMs make *artificially scarce* through technological enclosure.

The distinction between financial rents on loans and "technoscience" rents for "X-as-a-service" applications (Birch 2020; Sadowski 2020) is subtle but consequential for corporate power and consumer welfare. First, unlike the limited terms of a lease or loan, subscriptions are potentially indefinite (Arditi 2023). Even when a financed car is paid off, the owner will be required to pay monthly fees to access paywalled functionalities (Dhebar 2022). Economists have long known that subscription economics violate assumptions of rational consumption behaviors (e.g. DellaVigna and

[6] Subscription contracts are desirable for their reliability, predictability, above-average yields, and relatively short contract lengths (typically one year), which appeal during inflationary periods (Zhang 2022).

Malmendier 2006) and companies that generate revenue from subscriptions use every technique available to exploit that irrationality—to turn subscribers into "automatic customers" (Warrillow 2015) and sales into "forever transactions" (Baxter 2020). Those techniques include "dark patterns" that "trick or trap consumers into subscriptions" (FTC 2021) and onerous procedures that make cancellation difficult (FTC 2023).[7] So while subscription proponents prefer the term "stickiness" to "lock-in" (Shelley 2018), the goal of every subscription business is basically the same: increase "lifetime customer value" by making it costly or impractical for consumers to leave.

Splintering Ownership

Subscription, then, is *debt-like* because it creates consumer obligations to pay in regular installments, but it is also *unlike* debt because while those obligations are (in theory) voluntary or elective, they can never be paid off. By transforming vehicles into bundles of rentable functionalities (Dhebar 2022), subscription *splinters ownership*, turning consumers into partial renters and partial owners of their property, with implications for consumer protections. For example, because software subscriptions are subject to intellectual property law rather than consumer financial law, OEMs may face less stringent requirements of disclosure than lenders or creditors before obtaining a car owner's billing information.[8]

Carmakers justify this rentiership, in part, by claiming that over-the-air (OTA) software and firmware updates keep vehicles up to date with the latest capabilities, meaning that the subscriber-owner of a five-year-old car may have access to functions that were not available at the time of purchase. Smartphones are a common analogy. According to GM's Director of Software-Defined Vehicles, the integration of vehicle hardware and software through centralized control layers will "redefine the ownership experience [by] giv[ing] people the ability to update and improve their vehicles just like they can do with their phone" (GM 2021).

But if the smartphone analogy is common, it is also a double-edged sword. Some industry analysts worry that without a commitment to long-term software support from OEMs, vehicles could become obsolete relatively quickly, like smartphones—unable to receive or benefit from software upgrades within three to five years (Serpell 2021). Another concern is that OTA upgrades will negatively impact vehicular performance, just as Apple's software updates throttled the performance of older iPhones. In 2023, a group of Tesla owners filed a lawsuit against the carmaker, alleging that a mandatory update affected their vehicles' battery capacity, reducing driving range by as much as 20

[7] For example, the US Federal Trade Commission (FTC) alleged that Amazon developed an intentionally "labyrinth-like" process for consumers to cancel their Prime memberships. The cancellation process was known among Amazon employees as "the Iliad" because it made cancellation as tedious as reading a 15,693-line epic (Fair 2023).

[8] Rule changes by the US Federal Trade Commission (FTC) in 2023 partially cracked down on this practice (Warr and Asp 2023), but there is no guarantee that the updated rules survive the Biden administration.

percent and forcing some customers to pay out-of-pocket for new batteries (which can cost $15,000). Alongside infractions of California's unfair competition and computer fraud laws, the lawsuit suggests that Tesla may have violated trespassing laws in Illinois, Michigan, and Washington by interfering with owners' vehicles without permission (Crandall 2023).

Unlike smartphones, however, cars are consistently ranked as the second-highest expense for the average consumer in the US after housing (Bureau of Labor Statistics 2022). This makes depreciation a significant concern. Another rhetorical strategy has therefore been to liken new vehicles to real estate investment. Indeed, some carmakers have promoted a narrative that over-the-air subscription updates will make cars more valuable over time. Elon Musk, for instance, has claimed that Tesla customers were making "an investment into the future" because a Tesla is "an appreciating asset—not a depreciating asset" (Lambert 2019). Although the spike in auto prices following Covid-19 shortages lent some temporary credence to Musk's claims (Fortuna 2021), the market distortions would not last long. By Spring 2023, no vehicle had lost more value on the secondary market than the Tesla Model 3 (Bell 2023).

Characterizing subscriptionized vehicles as "appreciating assets" because of their upgradeability is not only misleading; it can negatively impact consumers. On the one hand, a vehicle's value should (in theory) reflect the deterioration of its parts over time. Engines, batteries, and other components inevitably wear down over time; subscription payments, however, remain steady and sometimes go up, meaning that subscriber-owners will be expected to pay the same amount, or more, for worse performance over time.

On the other hand, while adding expensive functionalities should increase vehicle values, this may not be the case with subscriptionized features, and the discrepancy could adversely affect borrowers who default on their auto loans. Not only will subscriptions add to some borrowers' financial strain and increase the likelihood of default, they could also increase how much borrowers owe lenders after a delinquency. Typically, lenders recoup about 30 percent of the loan value through vehicle repossession, leaving borrowers on the hook for the remainder (Fay 2023). If a borrower subscribed to an OTA upgrade—say, increased horsepower for $1,200 a year—that functionality could be reset by the OEM following a repossession, erasing the value of those upgrades from the borrower's equity and leaving them liable for more debt. And considering that automakers may also be the lender—and that automakers have started filing patents for self-repossession systems on connected vehicles (Stafford 2023)—such a scenario is not difficult to imagine.

Suffice to say, onboard vehicle subscriptions present worrying implications for car ownership (Perzanowski and Schultz 2016; Samuelson 2016). While some scholars argue that access-based models allow consumers to explore their identity without making long-term commitments to objects or communities (e.g., Kreiczer-Levy 2017), these benefits rest on the assumption that subscription replaces ownership, not that a gutted carapace of ownership survives alongside new forms of rentiership. With onboard vehicle subscriptions, automakers use the intellectual property protections of software licensing "to enact a form of micro-enclosure in which they retain ownership over the digital part of a physical thing—and all the rights and powers that entails—even after you

purchase it" (Sadowski 2020, 572–3). Subscriptionized features turn cars into "tethered devices"—products whose normal operation remains under sellers' control after a purchase (Hoofnagle et al. 2019, 785)—not for improved functionality but so they can ransom utility back to consumers, whose ownership may already be contingent upon existing forms of financial abstraction.

This splintering of ownership does not hinge on the development of new technologies per se; it simply requires enclosure. In fact, onboard vehicle subscriptions are built on top of infrastructures that were purportedly developed for public benefit, namely, environmental sustainability and safety. As we discuss in the next section, automakers are using these legitimate goals to justify an opportunistic repurposing of advanced technologies.

"The Building Blocks"

The idea that cars would one day become sophisticated computers on wheels, communicating with a central hub to execute complex computations on the fly, has shaped the sociotechnical imaginary of the automotive industry since its inception (Miller 2023). Although the paywalling and assetization of onboard vehicle features took off in the late 2010s and early 2020s, it relies on chipified systems whose development stretches back decades (Forelle 2022). Historically, the development of these systems responded to social or regulatory pressures to improve vehicle safety or reduce the environmental impacts of automobility. For example, automakers pursued electronic fuel injection in the early 1960s to satisfy government emissions standards requiring greater control over the use of fuel than what carburetors and other mechanical forms of fuel regulation were able to provide (ibid.). The first product to make use of vehicle telematics systems and over-the-air communications was GM's OnStar emergency services system in 1996. Subsequent computerized automotive technologies also focused on passenger safety, including systems that have become so ubiquitous that they are now federally mandated in all new cars and light-duty trucks, such as traction control, stability control, and backup cameras.

That OEMs continue advertising vehicles that are safer and more fuel-efficient is a testament to those qualities' enduring appeal to consumers. But for automakers, such outcomes are "table stakes," as a McKinsey study puts it (Grüntges et al. 2021). Hyundai representatives, for example, claim that subscriptions for software updates to customize car interiors could boost profitability by 30 percent (George 2023). But to start earning real money from subscriptions—what Mercedes-Benz CEO Ola Källenius calls "true, digital recurring revenue" (Patel 2022)—cars need centralized computational architectures capable of integrating vehicle software and hardware; they "need to have the tech stack available for these use cases" (George 2023). This is precisely where automakers have focused investment in recent years. GM and Stellantis released integrated platform architectures

in 2021, and Mercedes-Benz announced its end-to-end operating system in 2023.[9] Each represents a push to consolidate control over vehicle functions, not for the sake of improved safety, fuel-efficiency, or convenience, but as an architecture for generating revenue beyond the point of sale. As Källenius argues for Mercedes-Benz, "You have to have all those building blocks. If you do not have those, you certainly are not going to get that revenue. We are putting all the building blocks in place" (Patel 2022).

So, while the development of subscription's "building blocks" stretches back decades, we argue that the integration of vehicle software and hardware into streamlined platform architectures has accelerated dramatically in recent years as an opportunistic response to two distinct but related pressures: transitioning product lines from internal combustion engine to electric vehicles (EVs), and monetizing limited advances in autonomous vehicle (AV) technologies.

The EV Alibi

Gas-powered vehicles have historically dominated automobile production, but electric cars are actually older (Mom 2013). The first small-scale EVs were produced in the 1820s and 1830s in Hungary, the Netherlands, and the US. In 1900, 38 percent of all vehicles on the road in the US were electric (Richardson 2018). Over the next ten years, electric engines fell out of favor due to a variety of factors: the Ford Model T could be produced more quickly and cheaply; the short range of early EVs and limited availability of electricity outside major urban areas made longer-distance travel untenable; and the discovery of Texas crude oil made gasoline cheap and readily available (Department of Energy 2014). While the oil crises in the 1970s sparked some renewed interest in electric vehicles, it was only after the release of the Toyota Prius in 2000 and the Tesla Roadster in 2008 that real strides were made in public interest and consumer adoption of electric and hybrid-electric vehicles (ibid.). Coupled with advances in lithium-ion battery technology (Fletcher 2011), the popularity of these models spurred other automakers to take electrification seriously. At the time of writing, EVs are forecast to account for nearly two-thirds of global new-vehicle sales by 2035 (Irle 2023), although there is significant variation between and within countries (J. D. Power 2023).

EVs' growing market success—not to mention political pressure to address global warming by limiting carbon emissions—has galvanized governments around the world to set quotas and, in some cases, introduce outright bans on the sale of internal combustion engines. Between 2007 and 2017, at least 20 national and state actors adopted EV targets, including several countries in Europe that announced complete bans on the sale of internal combustion engine vehicles (ICE) by as early as 2025 (Meckling and Nahm 2019). In 2022, California announced a ban on gas-powered cars by 2035,

[9] The term "platform" does double duty for automakers—first, as a modular foundation for spinning up related but different product lines; second, as a digital interface to facilitate intermediation and control. See Steinberg 2022.

with Oregon and Washington following suit (Steves 2022). In April 2023, the US Environmental Protection Agency proposed new emissions standards that could push EVs to account for 67 percent of new vehicle sales by the 2032 model year.[10]

Automakers are now investing heavily in developing and promoting new EV lines, but they have also resisted the transition (Davenport and Boudette 2023). For one, EVs pose challenges to traditional automotive revenue streams due to their anticipated longevity. Electric engines contain fewer moving parts, so the prevailing assumption is that they will require less maintenance and repair, and are therefore likely to be on the road longer than gas-powered vehicles (Department of Energy n.d.).[11] OEMs expect fewer new vehicle sales over time, as well as fewer sales of authorized replacement parts, a prospect that also impacts automotive dealerships. As early as 2014, industry researchers warned that EVs would require automakers to "diversify their revenue streams" to compensate for the "considerable revenue" they would have captured from certified maintenance and parts for internal combustion engines (aftermarketNews 2014).

Another reason for resistance to electrification is that automakers claim EVs are less profitable than conventional gas-powered lines (Dow 2023). This is somewhat misleading: most new product lines—ICE or EV—are unprofitable for several years after their launch, and most electric lines are new. Still, EV production has been particularly affected by cost uncertainty and volatility. For example, pre-Covid-19 estimates concluded that EVs would reach cost parity with conventional vehicles by 2024 or 2025 model years (Lutsey and Nicholas 2019). Post-Covid-19 projections are more capricious due to supply chain disruptions and inflation. In June 2022, the cost of raw materials for manufacturing EVs had reportedly more than doubled pre-Covid-19 levels, pushing EV manufacturers to raise prices (Wallace 2022). Scarcely eight months later, some venues claimed that falling prices for raw materials, along with increased competition and government incentives, could bring cost parity with ICE vehicles as early as late 2023 (Ewing 2023); other sources believe EVs will remain expensive until automakers can "dramatically lower labor content" throughout the manufacturing process (Dnistran 2023).

This volatility is incentivizing automakers to streamline manufacturing at the same time that they are raising sales prices and pursuing more reliable streams of revenue, namely, from subscriptions and other software-driven offerings (DePillis and Smialek 2023; St. John 2023). In theory, subscriptions allow automakers to reduce costs by simplifying manufacturing and distribution. Instead of producing several models with different trims on spec, car manufacturers

[10] Achieving the EPA's quotas depends on which compliance pathways OEMs choose, and thus represents a much softer target than state-level or national bans.

[11] Interestingly, these assumptions have not yet come to bear. In fact, a Consumer Reports study concluded that EVs currently have 79 percent more reliability problems than ICE vehicles, although the researchers attributed these issues to the newness of the technology more than any inherent issues in EV engine design (Gitlin 2023).

could produce fewer, more customizable models, with advanced or luxury features pre-loaded and switched off until the car owner subscribes (Levin 2022). OEMs are also investing in solutions to minimize the number of chips needed for subscriptionized features, bringing down manufacturing costs even further (Baca 2022).

While reducing reliance on internal combustion engines may help curb emissions and halt global warming, automakers are using the EV transition as an excuse to consolidate control over, and monetize, vehicle functionality. Though software is necessary for many advanced functions, there is nothing inherent about battery-electric vehicles requiring that automakers enclose access to onboard functionalities after a sale. Automakers are therefore investing heavily to normalize the assumption that EVs must also be connected vehicles; that "apps designed to work natively with infotainment systems, over-the-air updates, in-car movies and gaming, and on-demand features" go "hand-in-hand with the EV transition" (George 2023). As CEO Jim Farley proclaimed in 2022 when announcing Ford's EV dealership programs, "We're going to see very large consolidation and big changes [in the industry]. . . . It's not motors and gearboxes, it's gateway modules and software that controls the vehicle" (Facundo 2022). Ford's Chief Financial Officer was no less bullish because, in his view, a "subscription-style business model" is a natural extension of Ford's investments in electric product lines: "[E]very module in the vehicle [will] be controlled by software and a central computer—that's where we're headed. That will be available when we launch our second-generation of battery electric vehicles" (Ottley 2022). If OEMs initially dragged their feet on meeting governmental mandates for EVs, the prospect of leveraging onboard subscriptions to "pull down Silicon Valley-style profits" has brought them back to the table (Levin 2022).

The AV Disappointment

This goal of attaining Silicon Valley-style profits is also motivated by a concurrent pressure on automakers to start making money from autonomous vehicle (AV) technologies. Throughout the 2010s, efforts to achieve driverless mobility pitted the auto and tech sectors in competition for talent and resources (Garibaldi et al. 2023). In response to tech giants' investments in self-driving divisions, automakers doubled their spending on in-house AV research and development (Korosec 2018). By 2015, automakers were establishing outposts in or near Silicon Valley to recruit programmers with expertise in machine learning, computer vision, and artificial intelligence (Davies 2022, 187; Love 2015). Following a wave of Big Tech layoffs in 2022, automakers jumped at the opportunity to snag software engineers (Garsten 2023), and more recently, started poaching executives. In 2023, Ford hired a former Apple executive to oversee the automaker's software integration "by consolidating [computing decisions] into a centralized processor powered by in-house software—a move that [would] make Ford EVs even more like an Apple iPhone with subscription services" (Johnson 2023).

As Forlano (2019) argues, the development of autonomous mobility has been shaped by a range of corporate and government-backed narratives and practices, including design charrettes, competitions, testbeds, and state-backed policies. These practices solidified throughout the 2010s into seeming guarantees of AVs' imminent arrival. For example, Musk famously announced in 2017

that Level 5 (that is, fully self-driving) autonomous vehicles would be available by 2019; GM's former CEO Mary Barra bragged that self-driving was "quarters, not years" away; and a year earlier, Ford set a 2021 target for driverless cars (Lee 2017). These optimistic forecasts were based on several myths, however. Despite billions spent to advance the state-of-the-art, AVs still face major technical difficulties (Fannin 2022; Korosec 2018). According to a 2022 analysis in *Semiconductor Engineering*, onboard computers have at best 25 percent of the processing power required for self-driving (and at worst only 8 percent), and at present, environmental sensors are too expensive for AVs to scale beyond trial cities (Baca 2022). Other thorny issues remain too, including the environmental impact of artificial intelligence (AI) systems in autonomous systems (Dhar 2020; Dixon 2020)[12] and lagging federal standards for safety and security of AI technology (Koopman 2022).

This disappointing reality has begun to sink in. In a notable pivot from earlier projections, Ford CEO Farley concluded in 2022 that "profitable, fully autonomous vehicles at scale [were] still a long way off" (The Economist 2023). Instead of a full-bore transition to autonomous vehicles, the industry has resigned to a more "evolutionary approach" (ibid.), with competition between the tech and automotive sectors giving way to market concentration. The map of the AV industry is now a sprawling network of financial entanglements and partnerships between legacy automakers and tech giants, AV startups, ride-hailing firms, academic institutions, and government agencies, signaling what one founder in the space called the "great consolidation" (Ho 2019; Marshall 2020). Industry analysts insist that alliances between Detroit and Silicon Valley are necessary for overcoming the final hurdles to "true" automation. But the corporate partnerships solve another problem too—monetization. "We are far, far away from universal acceptance" of AVs, an auto-tech consultant acknowledges, not only because of the lingering technical challenges, but because figuring out how to actually make money from self-driving vehicles is proving more difficult than expected: "[T]he business model is a bigger challenge than the technology" (Fannin 2022).

With Level 5 AV systems estimated to cost, realistically, around $250,000 per vehicle (LeVine 2017), and still requiring a "complex and costly back end of maintenance and operations" (Higgins 2022), a consensus seems to be emerging across the auto-tech landscape that, in the meantime, some form of subscription access to AV features is highly desirable (Deichmann et al. 2023). Instead of waiting to roll out driverless vehicles at astronomical price tags, charging subscription fees for pre-installed advanced driver-assistance systems (ADAS) "has the benefit of profits arriving sooner"

[12] Although we did not have space to consider it in depth, the environmental costs of the computation necessary for autonomous vehicles need to be accounted for alongside the benefits of electrification, especially since EVs and AVs are closely connected in industry discourse (e.g., Holland-Letz et al. 2021). Even partially autonomous driving in the form of ADAS is a computationally intensive endeavor that, like other artificial intelligence applications, generates a materially intensive supply chain, from rare earth extraction operations to global networks of carbon-pumping data centers (Cooper 2021; Hogan 2018; Pasek 2019; Forelle 2022).

(The Economist 2023). Unlike AV startups or even tech giants, automakers' investments in integrated platform architectures provide an infrastructure to actually start making money by selling access to "partial" advances in autonomous tech. Indeed, automakers are already marketing capabilities like automatic steering, adaptive cruise control, high-beam management, traffic-signal recognition, and parking assistance as high-tech safety features to reduce injury and fatalities from accidents, while simultaneously locking those features behind paywalls (e.g., Ebel et al. 2023). This more "evolutionary" approach to capitalizing on autonomous mobility is assuaging some investors' concerns (Carey and Lienert 2023; Higgins 2022). Rather than "wait years—or potentially decades—for an urban robotaxi service to begin generating profits," investors are happy to see OEMs start collecting "monthly ADAS subscription fees from millions of customers" (Hawkins 2023). Analysts project that by 2035, automakers will net as much as $400 billion in recurring, post-sales revenue from ADAS subscriptions and other pay-as-you-go safety options (Lewis 2023).

The Subscriptionized Ecology of Automobility

As automakers reluctantly accept their role mitigating environmental degradation and preventing avoidable death and injury, they are also exploiting these pressures to consolidate market power. We should understand such moves as examples of "greenwashing," or perhaps "autonowashing" (Dixon 2020), where automakers over-inflate the environmental or public health benefits of their products while leveraging public pressure for those advances as an excuse to restructure the entire sector. While paywalls have an obvious and immediate impact on consumers' budgets and welfare, they are also contributing to major transformations in how vehicles are sold, repaired, and regulated. That is, it is not only consumers who are subject to the techno-economic lock-in of subscriptionization, but the wider ecosystem of services, industries, and stakeholders surrounding automotive technologies.

Eliminating the Middleman

First, subscriptions are at the center of cat-and-mouse struggles between legacy automakers and dealerships. In the US, car dealers work closely with automakers and usually have exclusive rights to regional or local sales, but they are separate businesses whose interests do not always align (Tucker 2023). For example, OEMs have historically encouraged dealerships to accept trade-ins as a way to boost new vehicle sales (Schiraldi 2009) but they earn much less from the used car trade than dealers and other third parties. Subscriptions and other in-car purchases enable automakers to begin capturing after-sales revenue from which they were historically excluded—not only after initial sale or signing, but after any subsequent sale across a vehicle's lifespan, and dealers want their cut (Tucker 2023). Moreover, automakers' control of upgradeable features means that dealers have fewer opportunities to boost commissions by upselling customers on trim.

But dealership owners are also fighting subscriptions because of their association with EVs. As a group, dealers have resisted the EV transition perhaps even more vehemently than automakers. There are several reasons for this. First, EVs' longevity and relatively low maintenance requirements are expected to eat into dealership revenues from repairs and parts sales; second, as a politically

conservative group, dealers are skeptical of the environmental need for EVs; and third, dealership owners equate EVs with the direct-to-consumer sales model pioneered by upstart electric-only manufacturers, like Tesla and Rivian (Sammon 2023). This latter concern is valid: OEMs are now exploring the possibility of limiting dealers' retail discretion, if not cutting them out of the value chain entirely, in order to stay cost-competitive with EV-only manufacturers (Day 2022; Facundo 2022). In 2022, Ford CEO Farley publicly attributed Tesla's $2,000 USD per-vehicle advantage to direct sales and software-enabled subscriptions (Reuters 2022).

The National Automobile Dealers Association (NADA) is a politically powerful group in the US that has used its lobbying power at the state and federal level to ensure carve-outs and protections for dealership owners facing subscriptionization (Day 2022; Gitlin 2017). For example, many states prohibit legacy OEMs from selling to customers through over-the-air updates without compensating dealers (Gitlin 2017). Other states prohibit direct sales entirely, requiring manufacturers to sell their vehicles through independently owned dealers (Voelcker 2021). More recently, dealers have backed legislation to amend state franchise laws, which would either eliminate subscriptions entirely or ensure that dealers get a cut of the revenues (Tucker 2023).

Automakers have responded in turn by leveraging their market power to extract steep concessions from dealers. For instance, to participate in Ford's two-tiered EV retail program, dealers have to make major investments in charging infrastructure and expertise and adhere to strict new sales quotas, streamlined distribution models, and no-haggle pricing policies (Facundo 2022). GM, which plans to transition Buick to an EV-only brand called Electra, demanded similar concessions from its dealers. In this case however, only around half of the 2,000 Buick dealerships in the US accepted buyouts, opting to sell their franchises back to the automaker rather than comply (Walz 2023). Meanwhile, dealers who choose to abide automakers' demands are being instructed to embrace their new role "support[ing] customers with digital experiences like software and subscription products" (Bellan 2022).

Onboard subscriptions are thus part of a wider constellation of industry-wide changes that makes auto manufacturing much more integrated—internally, through proprietary software and hardware platforms, and externally, through organizational maneuvering designed to funnel a greater share of automotive revenues away from third parties and back to OEMs. Getting rid of dealerships, or curtailing their autonomy, are major steps in this direction, and may even benefit consumers in the short run by standardizing pricing and eliminating junk fees. But if the alternative to dealerships is vertically integrated, direct-to-consumer models, consumers may in the long run face even more obstinate legal and technical barriers to independent repair and maintenance (Hoofnagle et al. 2019).

(Right to) Repair, Maintenance, and the Aftermarket

Second, onboard subscriptions will make independent repair and maintenance unnecessarily complicated and expensive. Even before paywalls, the chipification of consumer vehicles transformed how automotive repair technicians are educated, increased the space needed to do their work (due to

system recalibration process requirements), and raised the costs of tools and data necessary to make repairs to chipified systems (Forelle 2022). Independent repair shops and aftermarket parts producers have to pay for access to diagnostic information and schematics, which are necessary for doing repair, maintenance, and aftermarket parts development for chipified vehicles (Warren and Gibson 2021). While some of this information can be bought outright, much of it is only available via paywalled access to platforms owned and run by the OEMs.

Subscriptionized functionalities add yet another layer of complexity. The digital tethering that makes paywalled features possible involves proprietary systems, which are fortified by a complex array of patents, software licensing, and digital rights management (DRM) mechanisms (Hoofnagle et al. 2019; see also Gillespie 2007). OEMs have even achieved carve-outs from right-to-repair exemptions to copyright law for features available by subscription, meaning that independent repairs to subscriptionized systems could be considered copyright infringement (Register of Copyrights 2021). And given that independent repair shops already struggle to offer repair services for advanced driver-assistance features (only about a quarter of non-dealership shops accept such repairs due to financial and training constraints), these barriers will only make independent repair even more costly (Elliott 2021; Mueller et al. 2023).

These carve-outs reveal how disingenuous, or at least superficial, analogies between smartphones and smart cars are. In the debates over consumer choice and right to repair, smartphones have historically been a site of notable gains. Consumers advocated for their right to "jailbreak" smartphones (i.e., bypass restrictions set by carriers) so vociferously that they were not only granted copyright exemptions years before cars, but succeeded in having those exemptions codified into US law through the 2014 Unlocking Consumer Choice and Wireless Competition Act. Fighting against provider restrictions was at the heart of consumer advocacy in this case—something that automotive executives and industry consultants overlook when they urge consumers to imagine their cars as "smartphones on wheels" (e.g., Herlt et al. 2022).

Like jailbreaking a phone, consumers are already finding ways to get around paywalls. Participants in the thriving, if niche, sub-industry of gray market hacker firms that help car owners bypass, disable, or turn on chipified car technologies have already begun offering services to circumvent subscription throttles on pre-installed features (Cox and Gordon 2022). Frustrated car owners are also helping each other with DIY workarounds. When BMW launched their subscription program for Apple's CarPlay infotainment system, BMW owners shared details through YouTube tutorials on how to leverage the Federal Supply Classification codes in their electronic control units to enable the feature without a subscription (Rivers 2022).

Subscriptions are also likely to have a significant impact on the third-party automotive aftermarket. One of automakers' selling points for subscriptionized features is that used-car buyers will be able to customize pre-owned vehicles to their preferences by accessing new subscription features to alter the vehicle's performance or aesthetics, a role historically filled by automotive aftermarket manufacturers, vendors, and service providers. To these suppliers, subscriptions will likely introduce another layer of corporate control in an ecosystem already constrained by design,

legal, and market strategies that work to OEMs' advantage. More recently, automakers have simply refused to provide some subscriptionized features in US states with rigorous right-to-repair protections (Bray 2023).[13]

These moves indicate how, despite often being treated as distinct regulatory concerns, right-to-repair and subscription protections are deeply intertwined. Federal agencies in the US have signaled a strong interest in protecting consumers' right to cancel subscriptions, repair their own devices, or choose their own independent repair options (Piepgrass and Thornhill 2022). While current efforts remain focused on subscription providers' predatory billing practices and manufacturers' illegal warranty stipulations, subscription features *by their technical and legal design* inhibit consumers' ability to access independent repair and aftermarket upgrades. Future regulatory efforts could work hand-in-hand with moves to update or expand laws like California's state requirement for parts availability, which stipulates that electronics manufacturers must make replacement parts and service literature available for at least seven years after the product was made (Hoofnagle et al. 2019). Extending such regulations to subscriptionized features may prevent the kinds of systemic enclosure that automakers need to extract rents from onboard functionality. For example, while the law currently only applies to hardware, Hoofnagle et al. (ibid.) and others suggest that it be expanded to include software.

Safety for a Premium

Finally, subscriptions may affect how automobility is regulated. Corporate interests, federal regulation, and user behavior have been pushing and pulling on automotive designs aimed at safety since the advent of the automobile. Most historians of the car seem to agree that, generally, corporate interests come out on top in these conflicts (Mashaw and Harfst 2017; Vinsel 2019; Norton 2021). Those with greater means generally have access to safer cars because safety requires the installation of more effective, and more expensive, materials and systems. However, with onboard vehicle subscriptions, this stratification occurs not because cheaper cars are sold without those safety mechanisms installed—OEMs no longer manufacture lower-end models that do not include them, so buyers do not even have the option to buy cheaper but less safe cars. Instead, buyers have to pay

[13] Most states require that automakers sell proprietary diagnostic tools and software to independent repair shops. In 2020, voters in Massachusetts decided by referendum to extend the state's right-to-repair law to include telematics and connected car services. Beginning with model year 2022, all new vehicles sold in Massachusetts must have a standardized open data platform that third-party and aftermarket suppliers can access (Gitlin 2022). In response to what automakers perceived to be overreach, Subaru and Kia both switched off their proprietary equivalents of OnStar for Massachusetts drivers. The carmakers claim this selective discontinuation was compliance; critics allege the decision was vindictive and deprived customers of critical safety features (Bray 2023).

upfront for the materials and manufacturing of safety systems and then make additional payments to access them. The safety is there, already installed and worked into the salestag, but paywalled.

While manufacturers claim that emergency-service systems like OnStar have saved thousands of lives (Glucker 2010), it goes unsaid that the lives saved are only those of people who can afford to pay the subscription fees. This troubling implication is exacerbated by the fact that many safety options today are only available a la carte. In 2023, for example, *Consumer Reports* found that several automakers were charging $100 USD per year for a pre-installed automatic crash-notification feature "and will disable it if that fee isn't paid" (Barry 2023). In a notable case, Volkwagen refused to help recover a car that had been stolen while a toddler was inside unless the owner, who was injured during the theft, agreed to pay $150 USD to restart its Car-Net connected car service (Brodkin 2023).[14]

Other features affecting safety have been locked behind paywalls as well. For example, in the South Korean market, all BMW vehicles are equipped with a "High Beam Assistant" that, for an annual subscription of £160 GBP, automatically turns high-beam headlights on or off. While BMW presents the feature in terms of convenience, this belies the extent to which high-beam etiquette impacts other drivers on the road. Tech writer Sean Hollister calls the update "don't blind other people" software:

> Let's forget the price for a moment, because that's not what infuriates me . . . [I]t's that the *rest of us* are depending on BMW drivers being such good citizens that they'll spend their own money to *avoid* showing off the power of their blazing headlights, all because a car company locked a perfectly good public safety feature behind a digital paywall. (2021; original emphasis)

Additionally, automakers have found ways to spin paywalled safety features as niche lifestyle choices. Hyundai touts upcoming subscriptions for in-vehicle climate control as an attractive option for car owners who might need to leave their dogs in the car during an errand (George 2023). Meanwhile, the National Weather Service reports an average of 38 childhood vehicular heat-stroke fatalities each year, in addition to hundreds of animal deaths (National Weather Service n.d.). Not locking this feature behind a paywall could save lives.

Putting public safety decisions in the hands of corporations is concerning in general but especially so during crises requiring the mass movement of people. In 2017 and 2018, Tesla enjoyed favorable headlines after extending the range of Model S and Model X cars for owners required to evacuate during Hurricanes Michael, Florence, and Irma (Lee 2018). While many observers credited Tesla for acting responsibly, the decision revealed that the cars' batteries were already capable of extended ranges but required an additional payment of up to $9,000 to access the remaining wattage.

[14] Volkswagen has since announced that they would make Car-Net free for five years on most 2020–2023 model year VWs. Volkswagens, known for their longevity, usually last 150,000 miles, which by rule of thumb translates to 10–15 years on the road.

Relying on corporations to make these decisions is risky if not dangerous: there is no guarantee that automakers will waive the fee or stop throttling vehicle features during the next crisis. Although considered categorically distinct, the ransoming of safety features through subscriptions warrants debate over whether the practice constitutes price gouging and should therefore be subject to greater regulatory scrutiny.

In the US, subscriptions may also affect how decisions over federal mandates for safety features are made because, presumably, mandates will mean prohibitions on paywalling. The National Highway Traffic Safety Administration, the federal agency that sets automotive safety standards, is a notoriously technology-following agency, meaning that it does not make automotive features a requirement until they are already fairly ubiquitous (e.g., Naylor 2012). If new safety features are marketed as conveniences and only offered as a la carte subscriptions, the agency could be more hesitant to make those features mandatory, especially if automakers collude to keep those features paywalled across the industry.

Conclusion

News of BMW's heated car-seat subscriptions sparked outrage among consumers, and the automaker noticed. In September 2023, BMW walked back its plans for heated-seat subscriptions. While executives insisted that subscriptions would provide consumers with more and better features, they also conceded that consumers did not see it that way. "People feel that they paid double—which was actually not true, but perception is reality" (Charlton 2023). Moving forward, BMW will no longer require payments to activate factory-installed hardware features. It will, however, continue selling "software and service-related products" for monthly fees, as these features seem to involve data transmission and "customers are used to paying for [that] in other areas" (ibid.). Meanwhile, other automakers continue charging for performance upgrades and battery-capacity expansions or promoting paywalled safety features as exciting new revenue sources.

Our contribution in this paper has been to examine the contingencies and consequences of this frontier of accumulation by situating the subscription-driven assetization of consumer vehicles in wider political-economic and sociotechnical context. First, we showed that while subscription payments resemble the receivables that OEMs have historically capitalized as financial assets, they are also distinct insofar as subscriptions impose enduring obligations that consumers can never satisfy and for which they accumulate no equity. This is consistent with the assetization literature, but we also highlight the exploitative *hybridity* of subscriptionized vehicles as partially ownable and partially rentable objects, which, like housing, have already been subject to decades of financialization (cf. Birch and Ward 2024, 10). Subscription reconfigures the already uneasy relationship between ownership, debt, and rentiership in ways that asymmetrically benefit automakers to the detriment of every other stakeholder in the automotive ecosystem.

Second, we argued that subscription paywalls are built on decades-old sociotechnical infrastructures that automakers are exploiting to consolidate control over vehicles as well as the automotive value chain. Automakers tout the public benefits of technological innovation while

obscuring the extent to which recent investments are narrowly focused on mechanisms of enclosure. Third, we considered the implications of subscriptionization for the broader ecology of the automotive sector, including retailers, regulation, and independent firms in the automotive aftermarket—namely, that subscriptionization exacerbates longstanding tensions in how automobiles are manufactured and sold, how automobility is governed, and how the concentration of market power makes repair and maintenance more costly for both third-party providers and consumers.

Subscriptions, in sum, are a fanciful illusion of empowerment painted onto a paywall. If automakers have their way, the future of automobility will be shaped by interests that run counter to consumer rights and public welfare. In the subscriptionized world, many of the most pro-social aspects of consumer ownership—the ability to tinker, thriving independent aftermarkets, a sense of connection to and responsibility for one's property (Samuelson 2016)—will have been foreclosed by models that allow corporations to retain control over consumers' property after the transfer of ownership. In the subscriptionized world, consumers become captured by a system that is like debt, but not debt, on top of increasing debt.

But as we have shown here, it is not only consumers that will be locked into these access-based models of feature design, implementation, and use. Turning vehicles into revenue-generating assets has the potential to create self-reinforcing path dependencies, with corresponding forms of technological, economic, and regulatory lock-in affecting entire sectors, including repair and collision, third-party aftermarket parts, transportation planning and regulation. These new path dependencies put something like BMW's calculated decision to not charge monthly fees for heated car seats in context. While the reversal may have been cause for celebration among BMW customers and consumer advocates, it is better understood as only a minor setback, a cautionary tale for automakers as they explore ways to normalize the enclosure of even more critical vehicle functions—next time, perhaps, without such loud pushback from consumers.

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