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On the Scales of Private Law: Nano Contracts

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ON THE SCALES OF PRIVATE LAW: NANO CONTRACTS

*Yonathan A. Arbel**

ABSTRACT

Contracts are falling in scale. New contracting trends and technologies facilitate the formation of smaller scale contracts that have ephemeral duration, token stakes, and narrow scope. These nano contracts embody ephemeral interactions of minuscule value — interactions that were previously far outside the law and away from explicit markets, governed only by social norms.

The rise of nano contracts can unlock new transaction types, create opportunities to build wealth, and reduce dependence on private ownership. Yet nano contracts also carry important risks, and their small scale makes them difficult to effectively regulate. At the limit, nano contracts collapse private law boundaries between property, torts, and contract, and would require a rethinking of the basic private law categories. This Article offers the first comprehensive study of these Lilliputian agreements, examining their potential while attending to questions of enforceability, market creep, and disparate impact. The analysis reveals the essential, if neglected, role of scale in private law, and how it can and should inform jurisprudence and policy.

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I. INTRODUCTION

THERE’S PLENTY OF ROOM AT THE BOTTOM.

— RICHARD FEYNMAN¹

In the 1959 annual meeting of the American Physical Society, theoretical physicist Richard Feynman stood up and took the stage, set to deliver a puzzlingly titled after-dinner speech.² With his signature mischievous grin, Feynman sought to persuade a room of physicists

1. Richard P. Feynman, *There’s Plenty of Room at the Bottom*, 16 *RESONANCE* 890, 890 (2011). Something will be lost from reading the transcript of Feynman’s lecture. Feynman later gave a similar talk, this time recorded, which is available online. Muon Ray, *Richard Feynman “Tiny Machines” Nanotechnology Lecture – aka “There’s Plenty of Room at the Bottom,”* YOUTUBE, (Aug. 22, 2012), <https://www.youtube.com/watch?v=4eRCygdW-c> [<https://perma.cc/DHE2-X3FB>].

2. Feynman, *supra* note 1, at 890.

that they should turn their gaze from the heavens above to the molecular level below. It is at the bottom — the smallest scale of atomic interactions — that we can find grand opportunities for innovation. In his inimitable style, he invited the room to imagine what it would be like to “swallow the surgeon,”³ to be able to replace the heavy hand of the surgeon with a pill containing a nano robot that performs operations with perfect precision. Miniaturization and development of nano scale technologies could lead to grand discoveries — or so Feynman claimed. But the room wasn’t quite ready for this message. His ideas were summarily dismissed as fanciful and outlandish.⁴ Time, however, stood on Feynman’s side. The nanotechnology revolution was built on Feynman’s ideas and exhortations.⁵ Today, nanotechnology is growing everywhere, from medicine to engineering, manufacturing, and science, attesting to Feynman’s prescience.⁶

There is plenty of room at the bottom for contracts too. This Article’s overarching argument is that (1) current technological trends show a dramatic miniaturization of contract scale and (2) the changed scale has deep legal implications. What I will strive to show throughout is that scale transformations do more than change the commercial aspect of transactions; they also carry the seed of social transformation. Drawing on examples of past scale transformations in contracts, it will become clear that a fall in contract scale can lead to broad social, political, and material changes. But while the march of technology is likely inevitable, the social response is not. Some of the changes carry great promise, promoting greater autonomy, choice, and prosperity. Yet, if the legal response is inattentive, these changes can also imperil social values, marginalized communities, and freedom. This Article works to illuminate both the promise and peril that lie at the bottom of contracts.⁷

3. *Id.* at 900 (recounting a similar nano robot hypothetical proposed by Albert R. Hibbs).

4. See Philip Ball, *Feynman’s Fancy*, CHEMISTRY WORLD, Jan. 2009, at 58, 61–62; Christopher Toumey, *Reading Feynman Into Nanotechnology: A Text for a New Science*, 12 TECHNÉ 133, 142 (2008). The lecture was only cited seven times in the first two decades after its publication. Editorial, *‘Plenty of Room’ Revisited*, 4 NATURE NANOTECHNOLOGY 781 (2009). At the time of writing, it boasts nearly 6,000 citations. *Richard Feynman*, GOOGLE SCHOLAR, <https://scholar.google.com/citations?user=B7vSqZsAAAAJ> [<https://perma.cc/YC97-KPUQ>].

5. This is so much the case that *Nature Nanotechnology* has a norm of forbidding authors from referring to Feynman’s lecture because it has become somewhat of a cliché. *‘Plenty of Room’ Revisited*, *supra* note 4, at 781 (referring to an unwritten rule to not reference Feynman’s lecture at the start of an article unless absolutely necessary).

6. See generally Debnath Bhattacharyya, Shashank Singh, Niraj Satnalika, Ankesh Khandelwal & Seung-Hwan Jeon, *Nanotechnology, Big Things from a Tiny World: A Review*, 2 INT’L J. U- & E- SERV., SCI. & TECH. 29, 29–36 (2009) (looking into the present and future usage of nanotechnology across different fields).

7. As emphasized throughout, the graveyards are full of failed predictions about the future of contracts, chief among them being GRANT GILMORE, *THE DEATH OF CONTRACT*

To motivate the analysis, consider the joint effect of some recent colinear trends in contracting practices: digitization of the contractual forms;⁸ cultural normalization of digital deals; the dispensation with wet signatures; the thundering rise of Everything-as-a-Service (“XaaS”) contracts;⁹ the tokenization and fractionalization of ownership; the ascendance of high-frequency trading (itself often a form of nano contracting);¹⁰ the increasing ability of artificial intelligence (“AI”) agents to effectively process natural language, negotiate, and transact;¹¹ and the persistent high-speed Internet connectivity of geolocated individuals and objects.¹² What ties these trends together is their creation of infrastructure that allows for the formation of agreements at near-zero latency and at asymptotically low transaction costs. These trends set the ground for a new breed of contract: nano contracts.

Nano contracts are digitally negotiated agreements that employ automated and near-instantaneous bargaining processes in multiparty peer-to-peer (“p2p”) transactions. What makes them *nano* is their scale. They cover transactions that last a few seconds; transfer cents, milles,¹³ and even smaller fractions of the dollar; or transfer slivers and fragments of the bundle of rights of ownership. Their p2p character reduces the need for intermediation, and thus allows parties to transact with each other without necessarily involving firms or platforms in the middle.

(1974). Part V offers a homage to this wonderful, if mistaken, prediction by hazarding an opposite future. *See infra* Part V.

8. *See, e.g., Aerotek, Inc. v. Boyd*, 624 S.W.3d 199, 210 (Tex. 2021) (“It may be that the use of electronic contracts already exceeds the use of paper contracts or that it will soon.”). The younger lawyer will be excused for assuming that electronic contracts are enforceable, but as recently as 2021, the Supreme Court of Mississippi held, as a matter of first impression, that the Uniform Electronic Transaction Act “permits contracts to be formed by electronic means, i.e. emails.” *Par. Transp. LLC v. Jordan Carriers Inc.*, 327 So. 3d 45, 48 (Miss. 2021).

9. For further discussions of the XaaS model, *see infra* notes 79–82 and accompanying text.

10. *See* Gianluca Piero Maria Virgilio, *High-Frequency Trading: A Literature Review*, 33 FIN. MKT. & PORTFOLIO MGMT. 183, 183 (2019) (“The relatively recent phenomenon of high-frequency trading has had a profound impact on the micro-structure of financial markets.”). In particular, the trading and (effectively) leasing of future contracts for the span of a few milliseconds is a large-scale demonstration of nano contracting and its potential.

11. *See generally* Yonathan A. Arbel & David A. Hoffman, *Generative Interpretation*, 99 N.Y.U. L. REV. (forthcoming 2024) (exploring the use of large language models (“LLMs”) to process language in legal settings).

12. *See Mobile Fact Sheet*, PEW RSCH. CTR. (Apr. 7, 2021) (reporting that eight-five percent of Americans own a smartphone), <https://www.pewresearch.org/internet/fact-sheet/mobile/> [<https://perma.cc/RJ3B-Z7U4>]; *infra* notes 74–82 and accompanying text.

13. Section 20 of the Coinage Act of 1792 defined the “mille” as a fraction of a cent. *See* Coinage Act of 1792, ch. 16, § 20, 1 Stat. 246, 250–51 (1792) (repealed 1873).

Two preliminary questions immediately present themselves. Is there anything truly new about these agreements if they are simply smaller scale contracts, and are these fleeting agreements even properly called contracts? On reflection, these two questions respond to each other. Classical concepts of definite position and momentum break down at the quantum scale. So do contracts. In classical contracts, the most basic distinction is between pure exchange relationships and contractual ones.¹⁴ This classification is based on certain assumptions about the identity of the parties, their capacity, the negotiation process, the values exchanged, and so on. Because these assumptions no longer necessarily hold, it is increasingly difficult to classify nano contracts as either contracts or spot exchange. The blurring of these two categories is what makes nano contracts so interesting to study.¹⁵

This point is best illustrated through a recent example. The rise of the gig economy brought its own scale transformation.¹⁶ Before the gig economy, short transportation agreements were mediated by the state through licensing and certification schemes.¹⁷ Uber and Lyft changed that by arguably disintermediating the relationship.¹⁸ Much of the recent lawfare around these platforms is about the classification of the agreements they facilitate. Is Uber an employer? What does it owe its drivers? Uber proposes that it only matches passengers to independent contractors for pay, and that this exchange does not amount to a contract, hoping to skirt the responsibilities of an employer.¹⁹ Drivers might like to emphasize a more contractual relationship between them and the platforms, for precisely the opposite reasons. The

14. True to the realist tradition, Arthur Linton Corbin advises that the very definition of what counts as a contract must not be made in a purely analytical fashion divorced from “our necessity and convenience.” ARTHUR LINTON CORBIN, *CORBIN ON CONTRACTS* 4 (1952).

15. The technical definition of contracts as a set of enforceable promises is frustratingly circular, but it does elucidate that if there is a nano contract, then it exists in the metaphysical promises rather than digital code. See RESTATEMENT (SECOND) OF CONTRACTS § 1 (AM. L. INST. 1981); *Contract*, BLACK’S LAW DICTIONARY (11th ed. 2019).

16. See, e.g., WEBSTER’S NINTH NEW COLLEGIATE DICTIONARY 517 (1985) (defining “gig” as “an entertainer’s engagement for a specified time”). The modern meaning is more diffused and contested. See Benjamin Della Rocca, *Unemployment Insurance for the Gig Economy*, 131 *YALE L.J.F.* 799, 802 (2022) (“The gig economy has no single definition.”).

17. See, e.g., *Medallion Owner, Individual*, NYC MYCITY, <https://nyc-business.nyc.gov/nycbusiness/description/medallion-owner-individual/about> [<https://perma.cc/CY7S-9BYN>].

18. See Orly Lobel, *The Law of the Platform*, 101 *MINN. L. REV.* 87, 98 (2016).

19. *People v. Uber Techs., Inc.*, 270 Cal. Rptr. 3d 290, 300 (Ct. App. 2020) (“The ‘Platform Access Agreement’ for Uber’s ‘Rides’ platform specifies that the parties’ relationship ‘is solely as independent business enterprises, each of whom operates a separate and distinct business enterprise that provides a service outside the usual course of business of the other.’”). Notably, when it came to Uber’s own terms of service, the company advocated for a thick contractual relationship with passengers. See *Meyer v. Uber Techs., Inc.*, 868 F.3d 66, 70–71 (2d Cir. 2017).

new technological form blurred traditional boundaries, resulting in novel and socially important questions about the scope of contracts.

Such legal encounters teach the general lesson that in law, scale has a quality of its own. Yet, as noted by Lee Fennell, scholars and policymakers have overlooked scale's role in creating powerful new (and sometimes fraught) legal configurations.²⁰ Nano contracts will bring their own questions about legal classification. Are nano agreements that let a party use another's driveway for a brief stop, for example, best understood as leases, licenses, or something else?²¹ Should ephemeral agreements to sell one's right of way be enforced as contracts? The small scale of nano contracts brings with it new questions which we have not yet considered, making our regulatory framework quite vulnerable to these developments.

The final preliminary question is how nano contracts might differ from other forms of digital contracts. The answer, which admittedly sounds like it comes from a college application, is focus and ambition. Unlike smart contracts, which are primarily tools of contract governance, nano contracts' focus and ambition is to solve the problem of contract formation.²² It is frustratingly difficult to create systems that allow for the creation of very small transactions, because even small frictions can overwhelm the value of truly small agreements.²³ Nano contracts address these issues using p2p digital protocols. Another possible distinction is that nano contracting technology does not require the blockchain or cryptography, although it could incorporate them if desired.²⁴ This marks nano contracts as a discrete form of transactional technology aimed at addressing the negotiation and formation bottleneck.

Nano contracts contain within them the germ of profound social and economic change. This germ, however, needs to be scrutinized before it spreads. A common saying in start-up culture is "move fast and break things."²⁵ This Article is interested not only in asking *what*

20. LEE A. FENNELL, *SLICES AND LUMPS* 3 (2019) (arguing that legal scholars have paid only "scattered attention" to divisibility in the law (i.e., slices and lumps, the subject of her book)). *Id.*

21. *See infra* Section V.B.

22. For a deeper exploration of these connections, see *infra* Section III.B.

23. *See* Oliver E. Williamson, *The Economics of Organization: The Transaction Cost Approach*, 87 AM. J. SOCIO. 548, 552 (1981) (exploring the role of frictions (i.e., transaction costs) in preventing valuable transactions).

24. Microgrids — community projects to generate, store, and transmit renewable energy in a peer-to-peer manner — are a relevant example. *See* Lea Diestelmeier & Job Swens, *Energy Communities in the Netherlands: Learning from Local Energy Initiatives*, EUR. ENERGY L. REP., Nov. 26, 2021, at 239, 252.

25. *See, e.g.*, Henry Blodget, *Mark Zuckerberg on Innovation*, BUS. INSIDER (Oct. 1, 2009, 4:36 PM), <https://www.businessinsider.com/mark-zuckerberg-innovation-2009-10>

will break, but also *whose* things are likely to break. Disruptive technologies, in a process of Schumpeterian creative destruction, often upend social and economic structures.²⁶ Nano contracts disrupt a large domain of common interactions that, due to their minuscule size and stakes, were previously left outside the market. Interactions such as waiting in the line at the deli are today mostly governed by social norms. Nano contracts will allow parties to turn these interactions into transactions. To market enthusiasts, this presents an opportunity to open new markets and create new forms of wealth. To market skeptics, nano contracting is yet another instance of market creep,²⁷ which will inevitably lead to excessive commodification, economic exploitation, and material disparities. After the gig and sharing economy revolution, the import of these questions is timely and salient. Uber, Airbnb, Taskrabbit, and other sharing economy platforms created newfound sources of wealth for some people on the margins of society.²⁸ But many other workers experienced financial losses and unemployment, neighborhoods saw property prices rise, and hotels faced a shrinking market.²⁹

This type of analysis requires consideration of future trends and concrete use cases. To weigh these considerations, this Article offers a variety of examples from diverse domains, some already deployed, others fast approaching, and yet others more imaginative. The nature of such projections is inherently uncertain and so a certain degree of suspension of disbelief around the particulars is warranted.³⁰ Niels

[<https://perma.cc/7QPE-N76E>] (stating that Mark Zuckerberg previously used this phrase as a “prime directive to his developers and team” at Facebook).

26. JOSEPH A. SCHUMPETER, CAPITALISM, SOCIALISM, AND DEMOCRACY, 81–86 (3rd ed., 1950). For a review of the evidence, see Arthur M. Diamond Jr., *Schumpeter’s Creative Destruction: A Review of the Evidence*, 22 J. PRIV. ENTER. 120, 120–22 (2006).

27. For a helpful review of the debates around market creep, see Kimberly D. Krawiec, *No Money Allowed*, 2022 U. CHI. LEGAL F. 221, 224 (2022).

28. See, e.g., Sophie Calder-Wang, *The Distributional Impact of the Sharing Economy on the Housing Market* 3 (Dec. 20, 2021) (unpublished manuscript), https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3908062 [<https://perma.cc/TXQ4-P3PC>] (estimating that Airbnb “host gains accrue heavily to a small fraction of households with particularly low costs of sharing, including low-income families”).

29. For a thorough, mostly skeptical view of the sharing economy, see Ronit Levine-Schnur & Moran Ofir, *Who Shares the Sharing Economy?* 51 (LSE L. Working Paper Series, Paper No. 19/2023, 2023), https://papers.ssrn.com/sol3/papers.cfm?abstract_id=4415934 [<https://perma.cc/CE3A-4TPX>]; see also Allyson E. Gold, *Community Consequences of Airbnb*, 94 WASH. L. REV. 1577, 1580 (2019); Jamila Jefferson-Jones, *Airbnb and the Housing Segment of the Modern “Sharing Economy”: Are Short-Term Rental Restrictions an Unconstitutional Taking?*, 42 HASTINGS CONST. L.Q. 557, 573 (2015).

30. On December 8, 1903, *The New York Times* ran a column decrying the folly of “flying machines which do not fly,” arguing that it will take centuries to develop a flying machine. *Flying Machines Which Do Not Fly*, N.Y. TIMES, Oct. 9, 1903, at 6. Nine days later, the Wright brothers announced the success of their trial. In 1943, IBM’s President allegedly said that, in his estimation, the world market for computers is for “maybe five computers.” FRED R. SHAPIRO, *THE YALE BOOK OF QUOTATIONS* 800–01 (2006). Even the more recent

Bohr was, after all, right: “It is hard to make predictions, especially about the future.”³¹

This Article is about scale, contracts, and technology. It naturally engages with conversations around the gig economy, platform regulation, and, more generally, consumerism and technology.³² It poses some timely questions surrounding the equitable distribution of the fruits of innovation. It also presses us to think carefully about the proper limits of markets in goods that, until now, have been unalienable due to the costs of negotiation.

The Article opens with a motivating thought experiment in Part II. Part III lays the foundations of nano contracts — where they fit along contracts’ history, what needs to be true for them to work, and what we can learn about their organization from their constraints. From this trunk, four limbs branch out. Part IV explores the implications of nano contracts on queues and the allocation of scarce resources; Parts V through VII explore the interaction between nano contracts and property, employment, and accidents. Part VIII concludes with some short reflections.

II. A PEDESTRIAN THOUGHT EXPERIMENT: NANO CONTRACTS AND THE FOUR-WAY STOP

To begin, let us consider a potential use case for nano contracts. Our opening thought experiment will be helpful in illuminating the potential, as well as the dangers and risks, of nano contracts. It comes from a routine, almost invisible interaction that takes place with great regularity: the four-way stop.

Four cars approach an intersection. The laws of physics prevent all cars from occupying the intersection at the same time. As they slow down, we witness the emergence of a valuable, but rivalrous

gig economy revolution was met with skepticism. Despite the very vivid precedent of taxi cabs and hotels, Uber was met with suspicion and Airbnb with incredulity. Who, in their right mind, would let complete strangers ride in their cars or invade their private homes? Derek Thompson, *Airbnb CEO Brian Chesky on Building a Company and Starting a ‘Sharing’ Revolution*, ATLANTIC (Aug. 13, 2013), <https://www.theatlantic.com/business/archive/2013/08/airbnb-ceo-brian-chesky-on-building-a-company-and-starting-a-sharing-revolution/278635/> [https://perma.cc/DRK7-VUVV] (“We thought, ‘This’ll work for one weekend to pay the bills while we come up with The Big Idea.’ People still said it was absurd.”); see also George Maier, *Will Uber Still Exist by the End of the Decade?*, LSE (Oct. 29, 2021), <https://blogs.lse.ac.uk/businessreview/2021/10/29/will-uber-still-exist-by-the-end-of-the-decade/> [https://perma.cc/8EXF-A5KV].

31. STANISLAW M. ULAM, ADVENTURES OF A MATHEMATICIAN 286 (1976).

32. Leading works on these issues include Lobel, *supra* note 18; Kate Andrias, *The New Labor Law*, 126 YALE L.J. 2 (2016); Julie E. Cohen, *Law for the Platform Economy*, 51 U.C. DAVIS L. REV. 133 (2017).

right: the right of way. How should society allocate this scarce resource? Admittedly, this is an odd-sounding question. We do not normally think of intersections and driving as problems of allocating scarce rights, but rather of obedience to the laws of traffic. Still, at a fundamental level, much of what traffic laws do is coordinate and allocate movement rights. And we want traffic laws do that job well.

Ideally, scarce rights should be allocated to those who need or value them the most. But traffic laws adopt a mechanistic allocation rule: first in, first out (“FIFO”).³³ A blind allocation of resources based on chance may fit some social settings, but this allocation loses luster when applied to actual road design. As a system, this distribution ignores many relevant moral facts such as need, urgency, or desert. Indeed, we encounter a common frustration every time we idle at an empty stop sign.

Realizing all of this, various actors have made tweaks around the edges. Urban designers try to adjust traffic light timing such that the odds of finding a green light will favor those on the more occupied road.³⁴ Legislators set rules such that when a real emergency erupts, ambulances and the police can usurp the right of way,³⁵ and, in some parts of the country, the rule is further tweaked by social norms of courtesy, although those are not uniformly observed.³⁶ Still, none of these tweaks do much to remedy the basic issue: antecedence is not an efficient or desirable method of allocating resources.³⁷

The problem is that it is hard to come up with a better system that increases fairness or efficiency. We have all been in situations where we were either late to an important appointment and needed some priority, or early with extra time to give. Most of us would see the utility — if not outright sanity — of a system where we could get priority when in a rush, and give priority when time is on our side. After all, to give our place in traffic to the car carrying a person in the throes of labor is a matter of basic decency. But such a system is un-

33. See Roney Perry & Tal Zarsky, *Queues in Law*, 99 IOWA L. REV. 1595, 1595 (2014) (describing the FIFO principles); Donald Wittman, *Efficient Rules in Highway Safety and Sports Activity*, 72 AM. ECON. REV. 78, 80 (describing the utility of FIFO for traffic allocation).

34. See Jeffrey W. Buckholz, CEDENGINEERING.COM, <https://www.cedengineering.com/userfiles/Introduction%20to%20Traffic%20Signal%20Timing-R1.pdf> [<https://perma.cc/5A2Q-HU28>].

35. See, e.g., N.Y. VEH. & TRAF. LAW § 1104 (McKinney 2023) (granting privileges to authorized emergency vehicles involved in an emergency operation).

36. For a broader analysis of allocation methods and preference algorithms, see *infra* Part III.

37. See Maram Bani Younes & Azzedine Boukerche, *An Efficient Dynamic Traffic Light Scheduling Algorithm Considering Emergency Vehicles for Intelligent Transportation Systems*, 24 WIRELESS NETWORKS 2451, 2452–54 (2018) (reviewing solutions that minimize the inefficiency of traffic light scheduling).

workable at scale. It is impossible to individually check each driver's level of urgency. Even if it were possible to inquire, why trust the answer? Nobody likes to sit in traffic.

Nano contracts offer a solution to this age-old problem. A nano contract application installed on every driver's car, phone, or autonomous driving system could allocate the right of way through automated bargains. Before beginning their journey, drivers enter their destination and their level of urgency, allowing the app to determine how much they value priority. As drivers approach an intersection, a silent auction is held, with drivers bidding in increments of pennies or in tokens for the right to pass through the intersection.³⁸ The driver who wins the auction receives the right of way, and the apps seamlessly exchange payments between them in the background. These negotiations are near-instantaneous and contain vanishingly low transaction costs. This process then repeats for those who come later as they automatically negotiate their place in line, receiving and sending nano payments as needed. For example, Brandon, who left late for his meeting with a wedding photographer but paid his way to arrive on time, is now \$3.10 poorer, but much happier. Nicole, who had a relaxing afternoon ahead of her, leisurely parks her car at her friend's house after collecting \$4.30 in fees along the way and brings her friend a cup of coffee.

Before addressing any issues, let us first stop and appreciate the achievement of this system. These Lilliputian agreements offer a robust solution to a vexing problem. As a system, nano contracts ensure that drivers' needs, rather than chance or order of arrival, allocate the right of way. Close analysis will show that the system is also fairer than the status quo and offers people a greater degree of control over their lives.³⁹ And because the system can run on priority tokens, rather than money, we can achieve all these efficiency gains while promoting equity and access.⁴⁰ Relative to our static system today, nano contracts offer a fluid dynamic. Traffic flows.

Nano contracts' utility is not limited to four-way stops. In the United States alone, there are approximately 411 billion car trips taken each day⁴¹ through a total of 330,000 traffic lights.⁴² If even a frac-

38. The hypothetical assumes two drivers at a single time. Generalizing this mechanism to an arbitrary number of drivers is possible but beyond this Article's scope.

39. See *infra* Section IV.B.

40. For further development of this point, see *infra* note 185.

41. See *National Household Travel Survey Daily Travel Quick Facts*, U.S. DEP'T OF TRANSP. (May 31, 2017), <https://www.bts.gov/statistical-products/surveys/national-household-travel-survey-daily-travel-quick-facts> [<https://perma.cc/372Q-M29W>].

42. See John Halkias & Michael Schauer, *Red Light, Green Light*, PUB. ROADS (Nov./Dec. 2004), <https://highways.dot.gov/public-roads/novemberdecember-2004/red-light-green-light> [<https://perma.cc/R843-GV3C>].

tion of those trips were governed by nano contracts, the potential benefits would be enormous. Traffic is far less stressful if, instead of fighting to keep your place, you make a couple of bucks by letting people pass you. And traffic is far safer if, even when people find themselves in a rush, they have a safer alternative to speeding that also ensures they arrive on time. If we can minimize idling time because priority cars do not need to come to a full stop, we can also reduce fuel consumption and noxious emissions.

This stylized example illustrates the potential that nano contracts can unlock. Hopefully, it also sparks a sense of curiosity. If nano contracts can solve these rote invisible inefficiencies, what other inefficiencies are currently hidden? What else can we solve with nano contracts?

Our example is also structured to elicit ethical and legal concerns. Applied without care, the use of nano contracts can result in priority given to wealthier parties.⁴³ Would nano contracting force poor drivers to treat every four-way intersection like an endless red light? Would they create a new source of income for some people or simply commodify yet another area of life? And then what happens in the nano contract world to the social norm of giving a friendly wave and letting another person pass before you? The commercialization and commodification of previously market-free areas may have a corrosive effect on social norms.⁴⁴ Or what happens if someone breaches their nano contract and lunges into a busy intersection? These issues are real, as are the potential benefits. The goal of the legal system is to anticipate these concerns and develop appropriate legal and regulatory frameworks to ensure that when nano contracts are deployed, they are implemented in a responsible and ethical manner.

III. FUNDAMENTALS OF NANO CONTRACTS: PLATFORMS, PROTOCOLS, AND LEGAL TECHNOLOGY

How much room is there at the bottom, and can we even get there? This Part discusses these two forms of skepticism. The skeptic's first reaction concerns the value of nano contracts. Nano contracts, the skeptic reasons, are unlike a new form of a leveraged buyout or some innovation in futures contracts. Those are the truly

43. The literature on toll roads finds that the distributional effects can be progressive, subject to the actual policy implementation. See Jonathan D. Hall, *Can Tolling Help Everyone? Estimating the Aggregate and Distributional Consequences of Congestion*, 19 J. EUR. ECON. ASS'N 441, 469–70 (2021); David Levinson, *Equity Effects of Road Pricing: A Review*, 30 TRANSP. REVS. 33, 33 (2010).

44. See *infra* note 195 and accompanying text.

important, innovative transactions. Nano contracts are small potatoes by definition. Do they deserve much attention?

Section III.A explains the skeptic's mistake. Blind to the role of scale in contracts, the skeptic is not only unprepared for the future of contracts, but also for their past. Examining the history of contracts from the perspective of scale, this Section demonstrates how every scale transformation was associated with profound and unpredictable social outcomes. Scale, we remind ourselves, has a quality of its own.

The second part of the skeptic's query challenges the feasibility of nano contracts in real-life situations. With such small stakes, practical concerns loom large. Section III.B responds to this challenge. Here, platforms and protocols make their first appearance, and they are shown to resolve these practical concerns. Platforms have great utility, but they also introduce market power. The alternative are protocols, which can also facilitate transactions without such risks, although they are harder to develop and maintain. But limitations notwithstanding, these alternatives render nano contracts feasible.

A. Scale and Contract Evolution

The future impact of smaller transaction scale is not easy to predict. Fortunately, it is easier to understand the past than predict the future. Let us consider, then, key points from contracts' history as they bear on the question at hand. To be sure, the story of contracts' past is not a simple one. These legal agreements reflect a complex web of social, political, and economic forces, each vying for influence.⁴⁵ What helps us see through this tangled web is thinking about contracts along a much simpler dimension: scale. As presently argued, over time the Anglo-American legal system has developed legal technology that supports transactions that are increasingly smaller and more flexible, allowing for more complex and varied interactions and social arrangements. This shift led to the paradoxical result that we see the simultaneous emergence of record-setting multi-billion-dollar

45. For competing narratives on the evolution of contract doctrine and its relation to political and moral theory, see Morton J. Horwitz, *The Historical Foundations of Modern Contract Law*, 87 HARV. L. REV. 917, 917–20 (1973); A. W. B. Simpson, *The Horwitz Thesis and the History of Contracts*, 46 U. CHI. L. REV. 533, 533–35 (1979). For a modern evaluation of these competing narratives, see Warren Swain, *A W B Simpson's, 'The Horwitz Thesis and the History of Contracts' (1978-1979)* 46 *University of Chicago Law Review* 533, 35 U. QUEENSLAND L.J. 115, 117 (2016). A caveat is in order: I confine myself to the Anglo-American common law world, although various parts of the analysis would apply beyond that legal system.

transactions among firms⁴⁶ and five-dollar contracts for gigs, among other fleeting engagements.⁴⁷

Take the move from status to contract. Under the manorial system, people were bound by all-encompassing legal arrangements known as status.⁴⁸ Status arrangements dictated nearly every aspect of the lives of the people living in the system and left little room for individual choices. These stringent sociolegal arrangements defined an individual as a serf, villein, vassal, and later indentured servant or peon.⁴⁹

These rigid structures of status were bound to crumble. As Henry Maine famously observed, the social pressures pent up: “[T]he movement of the progressive societies has hitherto been a movement from [s]tatus to [c]ontract.”⁵⁰ Over time, the old forms of status were stripped down to shorter, more modular transactions that were terminable and (warts and all) voluntary.⁵¹ Contract technology then allowed people to enter new forms of transactions including employment contracts, lease agreements, bailments, and warranties.⁵² None of these new forms of transactions emerged at a defined point in history; rather, they represent a protracted and uneven process where

46. The recent acquisition of Hess by Chevron provides a striking example. See Michelle Chapman, *Chevron Buys Hess for \$53 Billion, 2nd Megadeal in the Oil Patch this Month as Energy Prices Soar*, AP NEWS (Oct. 23, 2023, 6:05 PM), <https://apnews.com/article/chevron-hess-exxon-oil-merger-acquisition-37ff382d6fa713b7a1e887c7be5f1e93> [<https://perma.cc/W57V-RX98>].

47. The technological key is transactional modularity. On the relevance of smaller transactional blocks to handling complexity, see, for example, Henry E. Smith, *Modularity in Contracts: Boilerplate and Information Flow*, 104 MICH. L. REV. 1175, 1176–77 (2006) (discussing the characteristic costs and benefits of modularity); Cathy Hwang & Matthew Jennejohn, *Deal Structure*, 113 NW. U. L. REV. 279, 303 (2018) (explaining that, for complex systems, “modularity can successfully manage complexity that may otherwise overwhelm a system”).

48. Jonathan Bush offers an illuminating view of the role of “freedom” in this context. See Jonathan A. Bush, “*Take This Job and Shove It*”: *The Rise of Free Labor*, 91 MICH. L. REV. 1382, 1407 (1993) (reviewing ROBERT J. STEINFELD, *THE INVENTION OF FREE LABOR* (1991)).

49. It must be emphasized that the stylized picture here is a conceptual frame, rather than a linear historical account, which is based on HENRY J. S. MAINE, *ANCIENT LAW* (4th ed. 1906). Maine’s ambitious project remains influential despite various scathing critiques regarding its historical veracity and ideological bent, as eloquently recorded by Katharina Isabel Schmidt. Katharina Isabel Schmidt, *Henry Maine’s “Modern Law”: From Status to Contract and Back Again?*, 65 AM. J. COMP. L. 145, 158–63 (2017) (offering methodological, ideological, and substantive critiques to Maine’s thesis); see also Nathan Isaacs, *The Standardization of Contracts*, 27 YALE L.J. 34, 40 (1917) (arguing that feudalism was built on a move from contract to status).

50. MAINE, *supra* note 49, at 165.

51. As Bush notes, the emergence of contracts did not prevent the emergence of new coerced labor, such as “[indentured] labor and Indian peonage.” Bush, *supra* note 48, at 1404.

52. See Isaacs, *supra* note 49, at 35–37.

smaller scale transaction types slowly gained judicial, social, and political recognition.⁵³

The transition from large-scale “status” to the smaller units of “contract” has had a profound impact on society that continues to shape the way that people and businesses interact.⁵⁴ It can be difficult for a modern reader to fully appreciate the significance of this shift. Fortunately, Jonathan Yovel has provided us with a view from within one of these transformations by examining the travails of one prominent individual who lived through them: Johann Sebastian Bach.⁵⁵

As Yovel recounts, up until late in his adult life, Bach “served as a status-determined servant within a feudal hierarchy.”⁵⁶ This status designation constricted Bach and could have deprived the world of one of its greatest composers. When Bach tried to leave Weimar, “his seigniorial lord expressed his displeasure by having Bach incarcerated for almost a month.”⁵⁷ After many troubles, Bach was finally able to leave for Leipzig, where he became the celebrated musical director of the Thomasschule.⁵⁸ There, Bach was able to put his status-laden legacy behind him and sign his first significant formal contract.⁵⁹ It was then that Bach began to “talk contract.”⁶⁰ He may have, in fact, spoken contract too eloquently, as he soon found himself engaging in acrimonious negotiations and legal disputes with his new counterparties at the City Council.⁶¹ Thus, Bach’s transition was not a singularly sanguine story of redemption and empowerment. His letters portray a record of grievances and disappointments by a person who was, to put it with outmost respect, a real *nudnik*.⁶²

Still, even if Bach may not have always been thrilled with the new responsibilities and challenges of his contract position, he ultimately embraced the freedom and flexibility that it offered. Most importantly, he never went back. His experience exemplifies the larger

53. The Horowitz-Simpson debate echoes the protracted and sometimes incoherent emergence of modern legal doctrines. *See supra* note 45 and accompanying text.

54. *See generally* MAINE, *supra* note 49, at 165 (noting that the adoption of the Roman Codes facilitated “the distinction between stationary and progressive societies”).

55. Jonathan Yovel, *From Status to Contract: The Unhappy Case of Johann Sebastian Bach*, 27 *CAN. J.L. & JURIS.* 501, 502 (2014) (offering the life of Bach as a lens for understanding the transition from status to contract relationships).

56. *Id.*

57. *Id.*

58. *Id.* at 501.

59. The contract concludes with Bach’s formal seal and solemn promise to keep its terms. *See id.* at 512, 519.

60. *Id.* at 502–03.

61. *Id.* at 503.

62. Yonathan A. Arbel & Roy Shapira, *Theory of the Nudnik: The Future of Consumer Activism and What We Can Do to Stop It*, 73 *VAND. L. REV.* 929, 931 (2020) (explaining “nudniks” as consumers who take the time to “call to complain, complete satisfaction surveys, demand to speak with managers, post detailed online reviews, and file lawsuits”).

societal shift from status to contract, as millions of people around the world left feudal systems and entered a new era of economic and social interactions based on (comparatively) voluntary agreements.⁶³ Today, every market-based economy in the world relies on contracts as a central tool of resource allocation. From employment contracts and leases to warranties and bailments, we see in all of those smaller scale transactions how the shift from status to contract has irreversibly redefined business and individual interactions.

Less than two decades ago, a different transformative innovation took place: the birth of the gig economy.⁶⁴ Platforms like Uber,⁶⁵ Fiverr,⁶⁶ and Airbnb⁶⁷ transformed the way we work, travel, and do business, enabling the creation of short, small-scale contracts.⁶⁸ As the name alludes, at the heart of the gig revolution is scale, centered around the short and small scope of the engagement. Indeed, the gig economy downscaled contracts further and made them less lumpy and more targeted in scope, duration, and stakes.⁶⁹ Rover⁷⁰ transformed hiring a personal dogwalker into a single-walk deal; Fiverr converted general contracting agreements into a twenty-minute gig; and Airbnb reshaped private-residence subleases into a one-night proposition. By comparing the scale of gig economy contracts to standard lease, employment, or service agreements, we can conceptualize gig economy contracts as micro contracts relative to the macro contracts of traditional contracting.

To be sure, gigs were not a new concept when these companies first emerged. And the gig economy did not introduce any breathtaking doctrinal innovations. Rather, what is notable about the gig economy's impact is scale. The advent of Internet infrastructure has made

63. Schmidt notes how “Maine’s status/contract dichotomy is also reminiscent of Karl Marx’s movement from feudalism to capitalism.” Schmidt, *supra* note 49, at 153 n.19. Yovel further argues that “contract as a legal form and classical liberalism as a political model presupposing a theory of human nature, fit each other like glove to hand.” Yovel, *supra* note 55, at 503.

64. See generally Lobel, *supra* note 18, at 89–94 (describing the gig economy and its impact on legal theory and regulatory law).

65. *How to Use the Uber App*, UBER, <https://www.uber.com/us/en/about/how-does-uber-work/> [<https://perma.cc/9YZC-ENHR>].

66. *How Fiverr Works*, FIVERR, <https://help.fiverr.com/hc/en-us/articles/360010558038-How-Fiverr-works> [<https://perma.cc/87ZQ-QRQR>].

67. Carissa Rawson, *How Does Airbnb Work?*, NERDWALLET (Oct. 6, 2023), <https://www.nerdwallet.com/article/travel/how-does-airbnb-work> [<https://perma.cc/Z5NU-FRK9>].

68. See Samantha Delouya, *The Rise of Gig Workers is Changing the Face of the US Economy*, CNN (July 25, 2023) <https://www.cnn.com/2023/07/24/economy/gig-workers-economy-impact-explained/index.html> [<https://perma.cc/X9KX-SFKU>].

69. See FENNELL, *supra* note 20, at 137.

70. See *Why Should I Become a Pet Sitter or Dog Walker on Rover?*, ROVER, <https://support.rover.com/hc/en-us/articles/206351003-Why-should-I-become-a-pet-sitter-or-dog-walker-on-Rover> [<https://perma.cc/U7RS-YA9E>].

it possible, for the first time, to build large-scale marketplaces for small transactions, gigs, and other limited-term engagements. And just like the move from status to contract, we again see how smaller arrangements facilitated macro transformations.

Critics of the gig economy argue that it undermines workers' rights, unfairly disrupts the character of neighborhoods, and leads to the exploitation of foreign and domestic workers.⁷¹ At the same time, the gig economy brought with it enormous benefits, enabling people to work on their own terms and earn a living in ways that were previously impossible. Within this tension, one conclusion is indisputable: the downscaling of transactions has had a profound effect on the lives of people around the globe.

This short historical tour offers a clear response to the skeptic. Independent of any doctrinal or conceptual revolution, contract scale has always had a transformative effect on the transactional world. From status to contract and from contract to gig, nano contracts represent a general arc in the history of contracts. This history entails continuous downscaling of transactional blocks — to profound social effect. Of course, for nano contracts to fulfill this potential, they must be workable. The next Section moves to consider a systemic view of nano contracts from an engineering-economic perspective, revealing in the process the role of legal structures.

B. Nano Contracts as a Technology

Nano contracts use digital infrastructure to facilitate the automated, real-time, p2p bargaining processes between strangers. Such technology can wield different forms. In the four-way stop example, a nano contract app conducted an auction to determine which driver gets the right of way.⁷² But this is just one bundle of features for the implementation of nano contracts. In some cases, nano contracts may use fixed prices rather than auctions, and in others, they may facilitate exchanges based on barter, reputation, or even tokens.

While nano contracts' flexibility allows them to fit many use cases, this feature also makes nano contracts difficult to define.⁷³ Boundary setting is made more difficult because scale is not one-

71. See, e.g., Natasha Singer, *In the Sharing Economy, Workers Find Both Freedom and Uncertainty*, N.Y. TIMES (Aug. 16, 2014), <https://www.nytimes.com/2014/08/17/technology/in-the-sharing-economy-workers-find-both-freedom-and-uncertainty.html> [<https://perma.cc/AHL8-DRTD>] (“With piecemeal gigs easier to obtain than long-term employment, a new class of laborer, dependent on precarious work and wages, is emerging.”).

72. See *supra* Part II.

73. Their key feature, the small transactional scale, makes the task of drawing lines akin to deciding who is the world's largest small dog.

dimensional. Rather, scale covers the duration of the transaction, the stakes of the transaction, and the scope of rights transacted. And there may even be some conflict between these dimensions: a contract for leasing goods for a few seconds may still fetch a high value, for example, as we know from the pervasive high-frequency trading industry. These challenges notwithstanding, the examples provided in Parts IV through VII will cement some idea of the core and periphery of this concept.

Nano contracts arise from the natural continuation of the existing trends noted above, including the proliferation and normalization of digitized agreements, the growing digitization of goods and services, and the emergence of persistent connectivity at lower latency of geolocated individuals and objects.⁷⁴ These mutually reinforcing trends facilitate the ability — technologically, legally, and culturally — to form p2p contracts in real time at near-zero latency and at vanishingly low transaction costs. While each of these trends is worthy of full treatment, I focus on one recent trend overlooked by contracts scholars that lend special credibility to the emergence of nano contracts: the rise of the XaaS contracting model.

In the days of yore, people bought products from sellers and services from service providers. So central was the distinction that it was deemed fitting to construct an entire body of contract law that deals with one rather than the other⁷⁵ and then test neophyte lawyers on it. In recent years, a new model transitioning erstwhile products into services has started taking over, commonly abbreviated by the “aaS” suffix.⁷⁶ In the past, consumers would buy software like Microsoft Word and leave the store with a box with a hard copy of the code. Today, consumers are only subscribers to an ever-shifting piece of code.⁷⁷ We now have software as a service (Monday and Microsoft Office 365), infrastructure as a service (Amazon Web Services and Microsoft Azure), platform as a service (Google App Engine and Heroku), payment as a service (Square and Dwolla), and a dozen oth-

74. See *supra* note 12 and accompanying text.

75. See U.C.C. § 2 (AM. L. INST. & UNIF. L. COMM'N 1977).

76. Daniel Newman, *Why The 'As-A-'Service' Model Works So Well For Digital Transformation*, FORBES (June 27, 2017, 7:44 AM), <https://www.forbes.com/sites/danielnewman/2017/06/27/why-the-as-a-service-model-works-so-well-for-digital-transformation/> [https://perma.cc/75CA-3K83].

77. See Brien Posey, *Definition, Microsoft Office 365 Suite*, TECHTARGET (Oct. 2016), <https://www.techtarget.com/searchenterprisedesktop/definition/Microsoft-Office-365-suite> [https://perma.cc/B65M-83XD]; Tony Redmond, *Office 365 Reaches 345 Million Paid Seats*, OFFICE 365 IT PROS (Apr. 28, 2022), <https://office365itpros.com/2022/04/28/office-365-number-of-users/> [https://perma.cc/VG4L-UMMH].

ers.⁷⁸ One market report estimates that in 2023, the software-as-a-service market alone will be valued at 195 billion dollars.⁷⁹

A recent comprehensive study of the XaaS model has identified several market philosophy changes that the concept embodies.⁸⁰ Among these is what the authors perhaps not coincidentally call the “nanonization” of products.⁸¹ By this, the authors refer to the growing trend to disaggregate product bundles to the specific functions that the end user cares about. Farming as a service is an especially apt example. Tringo is one of a few platforms that offer farmers individual standalone services such as tractors, reapers, cultivators, and tillers which the farmer can access by simply tapping an app or calling a call center.⁸² While forty-five percent of the Indian workforce is engaged in agriculture, tractors are quite rare, averaging only one per village.⁸³ Tringo thus allows farmers an alternative to ownership, to pay only for the specific fragment of ownership if and when it is needed.

The advent of the XaaS model represents the growing “nanonization” of contracts and products. It demonstrates the market need for unbundled goods, the utility of specialization, the importance of small-scale transactions, and the robustness of the supporting technological infrastructure. One chief difference is that in nano contracts, parties will transact peer-to-peer rather than peer-to-firm. Even with a platform in the middle, the degree of intermediation in nano contracts is significantly lower than it is in the central firm model of XaaS.

At this point, it is useful to distinguish nano contracts from two seemingly adjacent technologies: the smart contract and the blockchain. Nick Szabo’s formative essay conceptualized the smart contract as a digital contract that algorithmically executes its own terms.⁸⁴

78. See, e.g., Ryan LaFlamme, *The Big -aaS List of As-a-Service Offerings*, <https://www.auvik.com/franklyit/blog/aas-as-a-service-list/> [<https://perma.cc/266L-SBJY>].

79. See, e.g., *Public Cloud Application Services/Software as a Service (SaaS) End-User Spending Worldwide from 2015 to 2023*, STATISTA, <https://www.statista.com/statistics/505243/worldwide-software-as-a-service-revenue/> [<https://perma.cc/3PDR-PT47>].

80. See SHANTANU BHATTACHARYA & LIPIKA BHATTACHARYA, *XAAS: EVERYTHING-AS-A-SERVICE* 5 (2021).

81. See *id.* at 5, 14–17.

82. *Id.* at 15; Ayesha Venkataraman, *How Do You Hail a Tractor in India?*, N.Y. TIMES (Oct. 17, 2016), <https://www.nytimes.com/2016/10/18/world/what-in-the-world/tringo-app-india.html> [<https://perma.cc/Q8WP-NT9L>]. Other services include Hello Tractor, Lucy Ngige, *Why John Deere invested in Africa’s Hello Tractor*, AFN (Aug. 16, 2022), <https://agfundernews.com/why-john-deere-invested-in-africas-hello-tractor> [<https://perma.cc/FHL7-VXH8>], and *Services*, FARMEE, <https://www.farmmee.com/services> [<https://perma.cc/2QN6-MJEN>].

83. BHATTACHARYA & BHATTACHARYA, *supra* note 80, at 14.

84. See Nick Szabo, *Smart Contracts: Building Blocks for Digital Markets*, EXTROPY, 1st Qu. 1996, at 50 (explaining that “[a] smart contract is a set of promises, specified in digital form, including protocols within which the parties perform on the other promises”).

More recently, Greg Klass offered a sharper definition, defining smart contracts as “software, perhaps run on a block chain, designed to execute future exchanges or other coordinated actions between persons who might not otherwise trust one another to perform.”⁸⁵ An insurance contract that automatically makes payments if a predefined event takes place is a typical example.⁸⁶

For our purposes, the crux of a smart contract is streamlining contract execution.⁸⁷ For this reason, many developers have used smart contracts with blockchain technology. In broad strokes, blockchain is a protocol that runs on tens of thousands of networked computers and creates a decentralized system of trade, meant to allow for trust among complete strangers with a central platform.⁸⁸ Just as the blockchain allows one to reliably send bitcoins to another, it can be adapted to run smart contracts that facilitate other forms of exchange. And so, while smart contracts do not require the blockchain, they often take advantage of it.⁸⁹ A review of smart contracts on GitHub repositories shows that 86.5 percent were tagged by authors with blockchain-related terms.⁹⁰

All of this highlights the key difference between the technologies. While smart contracts try to solve real or perceived problems of execution, nano contracts are tools of contract formation. They aspire to allow parties to create contracts at vanishingly low cost and near-zero latency. Whether the exchange is trusted or trustless is not a critical factor in the use of nano contracts. In fact, there are instances where smart contracts are too slow and expensive for the purposes of nano contracts, due to the blockchain’s relatively long settlement time.⁹¹

85. Gregory Klass, *How to Interpret a Vending Machine: Smart Contracts and Contract Law*, 7 GEO. L. TECH. REV. 69, 70 (2023). For other scholars’ definitions, see *id.* at 77–78.

86. See Kevin Werbach & Nicolas Cornell, *Contracts Ex Machina*, 67 DUKE L.J. 313, 331–32 (2017).

87. See Shaanan Cohney & David A. Hoffman, *Transactional Scripts in Contract Stacks*, 105 MINN. L. REV. 319, 321–23 (2020) (listing proposed uses and sources). The authors argue — persuasively on substance, less so in terms of marketing — that smart contracts are better termed “transactional scripts.” See *id.* at 323.

88. See *What is Blockchain Technology?*, IBM, <https://www.ibm.com/topics/blockchain> [<https://perma.cc/6AR5-Z5TD>]. At the time of writing, there are an estimated 16,300 reachable bitcoin nodes. See *Reachable Bitcoin Nodes*, BITNODES.IO, <https://bitnodes.io/> [<https://perma.cc/2QZW-GPG6>].

89. See, e.g., Mark Verstraete, *The Stakes of Smart Contracts*, 50 LOY. UNIV. CHI. L.J. 743, 757 (2019) (“[I]t is important to keep in mind that the principles and ideas behind smart contracts do not rise and fall solely on the promise of the blockchain.”).

90. For detailed explanation of the methodology, see Yonathan Arbel, *Smart Contracts and the Blockchain*, BATTLE OF THE FORMS (Dec. 7, 2022) <http://battleoftheforms.com/smart-contracts-and-the-blockchain/> [<https://perma.cc/P6D9-C5ZG>].

91. *A Deep Dive into Blockchain Scalability*, CRYPTO.COM (Jan. 3, 2020), <https://crypto.com/university/blockchain-scalability> [<https://perma.cc/3DKP-AV2Z>].

Whether nano contracts can achieve their goal instead depends on their practicability.

1. Practical Constraints That Nano Contracts Must Meet

To succeed in facilitating digital p2p contracts in real time, nano contracts must overcome certain challenges. Some of these challenges are legal in nature, while others are extralegal but still affected by legal norms. By understanding these constraints, we can come to understand how policies can contribute to, or stymie, the development of nano contracts. Drawing on the transaction cost framework applied by Michael Munger in the context of the sharing economy, we can identify five key constraints:⁹²

- (1) **Triangulation costs must be manageable.** Triangulation costs, as defined by Michael Munger, refer to the combined costs of locating potential service providers, settling on their price, and agreeing on terms.⁹³ Triangulation costs must be sufficiently low relative to the benefit, or surplus, of the transaction. Otherwise, parties will not form contracts. In the context of established markets for commoditized goods, triangulation costs can disappear into the background. But in other markets, they loom large. For example, while there is a large supply and demand for used cars, matching buyers and sellers is challenging.⁹⁴ Locating a seller with the specific required model, and then negotiating with them successfully, involves time, risk, and expense. To remove some of these frictions, people pay car dealerships significant amounts of money to create working markets. The challenge for nano contracts is that the transactional surplus is small. Therefore, triangulation costs must be exceedingly small in comparison to make nano contracts practical.
- (2) **Contract formation must be sufficiently streamlined.** The creation of the legally enforceable agreement cannot be too costly, or else parties would use alternative legal arrange-

(“While Visa can process up to 24,000 transactions per second (TPS), Bitcoin can process only seven TPS. Ethereum, Bitcoin’s closest competitor, can handle 20 to 30 TPS.”)

92. See generally MICHAEL C. MUNGER, TOMORROW 3.0: TRANSACTION COSTS AND THE SHARING ECONOMY (2018) (discussing the sharing economy and its relation to transaction costs).

93. *Id.* at 71–107.

94. See Charles Murry & Henry S. Schneider, *The Economics of Retail Markets for New and Used Cars*, in HANDBOOK ON THE ECONOMICS OF RETAILING AND DISTRIBUTION 343, 350–55 (2016) (explaining the benefits and burdens of personalized pricing and bargaining in a large retail market like those for new and used cars).

ments or informal arrangements, or abandon the deal altogether. This issue is familiar from history, as the primary means of contracting at early common law, the covenant, was rarely used due to its reliance on sealed written documents at a time when a significant portion of the population was illiterate.⁹⁵

For macro contracts today, these frictions are for the most part low — potentially even too low — relative to the value of the transaction.⁹⁶ But, for nano contracts, where the speed of formation is of the essence and the volume of transactions may be extremely large, per transaction, real-time expression of assent will add just enough friction and cost to make nano contracting all but impossible.

- (3) **Payment processing must be cheap and speedy.** If the costs of processing payments are too high, the parties will see no benefit in transacting. When buying a car, payment processing costs are usually inconsequential. But for small-scale transactions, like buying chewing gum at a gas station, payment processing costs can be prohibitive in relation.⁹⁷ Even some midscale transactions, like paying workers, are often delayed for weeks because of the alleged transaction costs of paying workers daily.⁹⁸ If drivers are to purchase priority at four-way stop signs, the payment must be smooth, quick, and most importantly, inexpensive.
- (4) **Dispute resolution must be available, trustworthy, and efficacious.** In the event of a breach of contract, a party can sue in court. But for many small-scale consumer transactions, standard court proceedings are prohibitively costly, making it

95. See, e.g., JOHN BAKER, AN INTRODUCTION TO ENGLISH LEGAL HISTORY 338–42 (5th ed. 2019) (discussing the history of the covenant in English courts).

96. For an unwavering attack on form contracts, see David A. Hoffman, *Defeating the Empire of Forms* 4–5 (Inst. Law and Econ. Working Paper No. 23-04, 2023) (challenging the proliferation of explicit, formal, and long-winded contracts for low-value transactions); Mark A. Lemley, *The Benefit of the Bargain*, 2023 WIS. L. REV. 237, 238–39 (arguing that “society has lost the ‘benefit of the bargain’ contract law once promised” due to the proliferation of written agreements).

97. Some credit card companies charge a per-transaction fee, which eats into the merchant’s margins. See, e.g., Billie Anne Grigg, *PayPal Fees and Rates List for Small Businesses*, NERDWALLET (Oct. 23, 2022), <https://www.nerdwallet.com/article/small-business/paypal-fees> [<https://perma.cc/7NRA-VTYM>]. As a result, merchants often want to discourage the use of credit cards for small transactions. Under the Dodd-Frank Act of 2010, merchants are allowed to set minimum amounts for credit card purchases that do not exceed \$10. 15 U.S.C. § 1693o-2(b)(3)(A).

98. See Yonathan A. Arbel, *Payday*, 98 WASH. U. L. REV. 1, 1–8 (2020) (explaining why abolishing the payday is “desirable, efficient, and surprisingly feasible”).

necessary to use alternative mechanisms such as class actions or small claims courts. The absence of effective dispute resolution has been linked to the loss of significant transactional surplus.⁹⁹ In the four-way stop example, what happens if a driver speeds into the intersection, ignoring the nano contract?

- (5) **Enforcement must have a sufficient deterrent effect on noncompliant parties.** For macro contracts, enforcement issues arise with some regularity, yet this problem is not sufficiently pressing to undermine the entire system. Some parties evade service, impose delays on the process, and engage in distractions. Yet, as long as the party is not judgment-proof — or poses no credible threat of making herself judgment-proof — the threat is considered acceptable.¹⁰⁰ If a sanction exists, it must have sufficient bite to ward off unwanted behavior.

2. How Nano Contracts Can Meet These Constraints

These constraints appear foreboding at first. The nano stakes of nano contracts make the system particularly fragile to practical concerns because, at this scale, there is just too little surplus to cushion transactional costs. Fortunately, there is a proven answer for most of these issues. The downscaling of macro contracts to micro contracts in the gig economy has already answered many of these concerns.¹⁰¹ These answers largely involve two supporting mechanisms — platforms and reputation — although neither is perfect. The following discusses these answers in order.

Triangulation Costs. The gig economy faced this problem in earnest. It is costly to triangulate partners for any deal, and for small deals in particular. That is one central reason why the gig economy had to wait in the shadows for so long. The solution, enabled by technology, was the reinvention of an old concept: the two-sided marketplace. The ancient concept of the bazaar proved something that might

99. See Simon Johnson, John McMillian & Christopher Woodruff, *Courts and Relational Contracts* 2–5 (Nat'l Bureau of Econ. Rsch., Working Paper No. 857, 2001).

100. See generally Yonathan A. Arbel, *Shielding of Assets and Lending Contracts*, 48 INT'L REV. L. & ECON. 26 (2016) (exploring the problem of judgment-proofing as a strategy of avoiding legal enforcement).

101. See generally Seth Oranburg & Liya Palagashvili, *Transaction Cost Economics, Labor Law, and the Gig Economy*, 50 J. LEGAL STUD. S219, S227 (2021) (conducting an analysis of the gig economy's transaction costs).

otherwise appear counterintuitive:¹⁰² merchants are better served when they are located adjacent to other, especially in the case of competing merchants, because it is easier for buyers to find an appropriate seller.¹⁰³ Companies like Uber and Airbnb adopted this model with an additional spin: they moved buyers and sellers to virtual spaces.

Another solution that avoids the use of platforms is the use of protocols.¹⁰⁴ Protocols are standards of communication that allow transacting parties to locate each other and communicate directly. One example of a protocol that works at scale comes from blockchain-based exchanges, where two strangers can transfer value without the intermediation of a platform. The Internet itself also demonstrates the power of standard protocols in coordinating multiparty information exchanges, with relatively little centralized authority.

As applied to nano contracts, we can think of a spectrum of solutions to the triangulation problem differing in the degree of intermediation. We can conceive of systems of centralized ordering, which are heavy in intermediation, such as those organized by airlines that sell priority when boarding the airplane. Less decentralized are platforms, which can help maintain a marketplace and means of communication between interested parties, such as the various online stock and crypto exchanges. And then we can think of direct communication protocols, which involve no third-party mediation.

Platforms promise, as Orly Lobel notes, “no more middleman, besides — of course — the platform.”¹⁰⁵ The rise of platforms raises various concerns, perhaps most notably the rise of monopolies in the presence of network effects.¹⁰⁶ Protocols are more attractive on this score, but their design, maintenance, and difficulty of propagating updates are still real costs that must be borne.¹⁰⁷ Fortunately, open-

102. See generally Clifford Geertz, *The Bazaar Economy: Information and Search in Peasant Marketing*, 68 AM. ECON. REV. 28 (1978) (emphasizing high search and information costs in an analysis of the bazaar marketplace’s economics).

103. For a study of the impact of spatial clustering on competition, see Harold Hotelling, *Stability in Competition*, 39 ECON. J. 153 (1929).

104. For a comprehensive analysis of protocols and the subtleties of architecture design and regulation, see, for example, Christopher S. Yoo, *Protocol Layering and Internet Policy*, 161 U. PA. L. REV. 1707, 1716–17 (2013) (describing the conceptual underpinnings of protocol layering).

105. Lobel, *supra* note 18, at 110.

106. See generally Bruno Jullien, Alessandro Pavan & Marc Rysman, *Two-Sided Markets, Pricing, and Network Effects*, in HANDBOOK OF INDUSTRIAL ORGANIZATION 485 (Kate Ho, Ali Hortaçsu & Alessandro Lizzeri eds., 2021) (exploring two-sided markets and monopoly concerns).

107. The Bitcoin protocol is the best exemplar. There, disputes about updates to the protocol have created community schisms. See Chelsea D. Button, *The Forking Phenomenon and the Future of Cryptocurrency in the Law*, 19 UIC REV. INTELL. PROP. L. 1, 9–11 (2019).

source communities and government-funded standard-setting organizations provide workable models for such implementations.

Contract Formation. The solution for the formation problem in the context of nano contracts relies on advance consent and automated negotiations. This allows the app to negotiate in real time with very little latency or cost — even in the form of attention.

Some scholars argue that automated contract formation is problematic, at least when the question arises in the context of smart contracts.¹⁰⁸ The contracting script lacks agency, they reason, and so it cannot manifest the necessary assent required to enter into a contract.¹⁰⁹ The same holds for nano contracts, which will likewise have to rely on automated formation methods and advance expressions of assent.

This view of contractual assent is open to debate.¹¹⁰ While everyone agrees that lack of assent is a bar to enforcement, the procedural forms of expression of assent are a different matter. Authorizing an offer or acceptance by proxy is not an issue in modern contracting, as agency law and, well, the ability of any corporation to form valid contracts, make obvious.¹¹¹ Nor is the introduction of digital assent especially problematic, given how consumers routinely enter — and courts enforce — online contracts.¹¹² Again, there are good reasons to worry about faulty assent, but the medium of assent is orthogonal to these concerns. If we question the validity of clickwrap agreements, it is not because the words are shown on a screen, but because they are not read or understood.

108. See, e.g., Amy J. Schmitz & Colin Rule, *Online Dispute Resolution for Smart Contracts*, 2019 J. DISP. RESOL. 103, 105 (“It also may be difficult to fit square concepts of offer, acceptance and consideration into the round hole of smart contracts.”).

109. See *id.*

110. For a similar conclusion, see Klass, *supra* note 85, at 72. (“Those transactions pose no special formation issues. In other instances, however, parties might express their agreement solely by using a smart contract, without an accompanying verbal agreement, recalling a vending-machine transaction.”).

111. See RESTATEMENT (THIRD) OF AGENCY § 1.04(2)(b) (AM. L. INST. 2006).

112. Scraping may appear at first sight to challenge this thesis, as several courts have ruled that automated web access does not create consent to terms of service. However, those cases are deeply rooted in questions of copyright preemption rather than any substantive view on the quality of consent. See, e.g., *Genius Media Grp. Inc. v. Google LLC*, No. 19-CV-7279, 2020 WL 5553639, at *7 (E.D.N.Y. Aug. 10, 2020), *aff’d sub nom.* *ML Genius Holdings LLC v. Google LLC*, No. 20-3113, 2022 WL 710744 (2d Cir. Mar. 10, 2022). In any event, digital contracts are just as binding as their offline counterparts, as modern battles are waged over *form* contracts.

Recently, Mark Lemley offered a scathing critique of the modern practice of contract enforcement of clickwraps, terms of use policies, and similar standard form contracts. See Lemley, *supra* note 96, at 252–56. These concerns target, however, the issue of consent and deliberation rather than timing or method. Depending on their specific implementation, nano contracts may well escape the crosshairs of his and similar critiques.

That nano contracts rely on preestablished manifestations of assent is likewise immaterial. If a merchant considers buying oil and deposits an offer to buy a number of barrels with her agent, telling the agent to “negotiate with a willing seller if market conditions improve,” then the merchant’s offer is effective.¹¹³ As long as there is a verifiable pedigree of assent, it matters little for nano contract formation that the medium is digital, that assent is preestablished, or that it is conveyed via algorithm.¹¹⁴

Payment Infrastructure. It is surprisingly expensive to transfer payments. These costs make it difficult to implement any system of micropayments.¹¹⁵ This is because traditional payment systems were designed for large, not small, transactions. As a result, the fees associated with these transactions can be quite high, making them impractical for use in micropayment systems.

Fortunately, financial technology (“fintech”) start-ups, and to a lesser extent, cryptocurrencies, are increasingly building solutions to these problems. For example, PayPal offers the option to transfer payments between friends and family at no cost.¹¹⁶ While this remains a far cry from a costless system of money transfers, developments in the payment space continue to grow.¹¹⁷ In the meantime, the gig economy resolved this issue through platform-side accumulation. In those regimes, interim payments accumulate after every ride, and the platform sends payment in a single beat, either after a period of time or after meeting a minimum withdrawal limit.¹¹⁸

Nano contracts must adopt one of three solutions. They can use platforms to accumulate payments before transfers; they can rely on alternative financial tools, like crypto tokens, that are cheaper to

113. See RESTATEMENT (THIRD) OF AGENCY § 6.01 (AM. L. INST. 2006).

114. Greg Klass makes a similar point using a vending machine analogy. Klass, *supra* note 85, at 85 (noting “the use of a vending machine can create a legal contract between the user and the machine’s operator”).

115. See Arbel, *supra* note 98, at 31–34; see also Peter Conti-Brown & David A. Wishnick, *Private Markets, Public Options, and the Payment System*, 37 YALE J. ON REG. 380, 393 (2020).

116. *What’s the Difference Between Friends and Family or Goods and Services Payments?*, PAYPAL (June 22, 2022), <https://www.paypal.com/us/cshelp/article/whats-the-difference-between-friends-and-family-or-goods-and-services-payments-help277> [<https://perma.cc/GK73-YZGQ>].

117. See Franklin Allen, Xian Gu & Julapa Jagtiani, *A Survey of Fintech Research and Policy Discussion*, 1 REV. CORP. FIN. 259 (2021).

118. For example, Lyft pays its drivers on a weekly basis. *When Does Lyft Pay?*, ZIPPAA (July 31, 2023), <https://www.zippia.com/answers/when-does-lyft-pay/> [<https://perma.cc/RVG2-RFE3>]. Uber offers a more elaborate scheme, where drivers who do not want weekly pay can cash out immediately for a fee, which may be waived if they have a special Uber Pro Card. *Your Money When You Want It*, UBER, <https://www.uber.com/us/en/drive/driver-app/instant-pay/> [<https://perma.cc/JKK2-PKJM>].

transmit over an agreed protocol;¹¹⁹ or they can wait until payment infrastructure improves. A more general lesson from this analysis is that the issue of payments highlights one source of platform market power — the inefficiency of payment infrastructure — and therefore presents a different avenue for reducing the dependence on platforms.

Dispute Resolution. Perhaps the most sensitive part of small-stake contracts is dispute resolution. The problem is well-known: dispute resolution systems are expensive to operate, their decisions are protracted, the *de minimis* doctrine bars litigation,¹²⁰ and they are generally a poor fit for small-stake disputes.¹²¹ But if disputes are never settled, parties can breach with impunity, undermining the entire system. The legal system has developed several mechanisms to deal with small-stakes disputes, from cheaper arbitration, mediation, and conciliation processes to stake aggregation via class actions and group litigation.¹²² Yet, for very small-scale transactions, especially those that are heterogenous, these solutions can only provide a partial solution. Thus, the gig economy came to rely on two complementary mechanisms: reputation¹²³ and in-house adjudication.¹²⁴

Reputation has proven itself a major disciplining force. To see its role in the private ordering of small transactions, consider the consequences of breach. Suppose an Uber driver does not live up to the expected standard — the car is messy, the driver casually scans their phone while driving, and grating music blares from the speakers. These issues violate the passenger’s transactional expectations, but none would command sufficient stakes to warrant a lawsuit.¹²⁵ The solution is a personal accountability system, in the form of reputa-

119. Cryptocurrencies are still not quite there. Between August 2021 and April 2023, Bitcoin’s on-chain transaction cost ranged from around \$0.95 to \$2.40. See BLOCKCHAIN.COM, <https://www.blockchain.com/charts#currency> [<https://perma.cc/6NHF-B5R7>].

120. See, e.g., *Harris v. United States*, 232 F.3d 912 (Fed. Cir. 2000).

121. See Christopher R. Drahozal, *Arbitration Costs and Form Accessibility: Empirical Evidence*, 41 U. MICH. J.L. REFORM 813, 840–41 (2008) (finding it unclear whether arbitration is much cheaper than litigation after summarizing empirical evidence on arbitration costs).

122. See STEVEN P. CROLEY, *CIVIL JUSTICE RECONSIDERED* 185–223 (2017) (discussing the problem with access to the courts).

123. See Rory Van Loo, *The Corporation as Courthouse*, 33 YALE J. ON REG. 547, 552 (2016) (noting that the corporation plays a “key dispute resolution role as a reputation-based enforcement mechanism”).

124. *Id.* at 559 (“In recent years, companies have expanded consumers’ ease of access to the settlement process by developing social media departments.”).

125. Of course, passengers are less likely to use the platform if the overall riding experience is poor. However, since the “riding experience” is a public good and each driver has minimal influence on it, drivers may be inclined to act without considering the collective experience, leading to a free-rider problem. See generally Michael Luca, *Designing Online Marketplaces: Trust and Reputation Mechanisms*, 17 INNOV. POL’Y & ECON. 77, 78 (2017) (describing the design challenges that arise in online marketplaces).

tion.¹²⁶ Uber prompts passengers and drivers to leave a reputational signature by reviewing each other. If a driver consistently underperforms, she suffers the risk that passengers will refuse to ride with her.¹²⁷ If a passenger is rowdy or aggressive, she might find herself with no transportation. Research shows that, while imperfect, these systems effectively promote good behavior among users, even in the absence of litigation.¹²⁸

Platforms use another solution, which they normally reserve for more meaningful transgressions: the “corporate courthouse.”¹²⁹ In these internal dispute resolution mechanisms, both parties can explain their position, usually in a limited fashion and without legal representation, and the final adjudication is given to an employee of the platform.¹³⁰ The platform will often issue a quick refund, preferring to err on the side of the user and resolve the matter internally with the service provider.¹³¹ Of course, the platform compensates itself for such services. But by putting itself in the middle, it also opens itself to class actions and regulatory interventions. These features of the “corporate courthouse” may ameliorate some of the concerns we might have with platform power.

Finally, even though the stakes are small, the legal system is not absent. For example, in the case of a four-way stop,¹³² if a driver breaches a nano contract and causes an accident, the resulting higher stakes conflict will introduce the legal system directly. The court will deem the breaching driver as being at fault for the accident, analogous

126. See Ngai Keung Chan, *The Rating Game: The Discipline of Uber’s User-Generated Ratings*, 17 SURVEILLANCE & SOC’Y 183, 183–84 (2019) (discussing the effects of ratings, and fear of falling ratings, on Uber drivers).

127. Indeed, Uber expels low reputation drivers. James Cook, *Uber’s Internal Charts Show How Its Driver-Rating System Actually Works*, BUS. INSIDER (Feb. 11, 2015) <https://www.businessinsider.com/leaked-charts-show-how-ubers-driver-rating-system-works-2015-2> [https://perma.cc/782D-93Y2].

128. For example, Uber drivers take much shorter routes with nonlocal passengers, relative to taxi drivers. See Meng Liu, Erik Brynjolfsson & Jason Dowlatabadi, *Do Digital Platforms Reduce Moral Hazard? The Case of Uber and Taxis*, 67 MGMT. SCI. 4665, 4665–67 (2021).

129. See Van Loo, *supra* note 123, at 547.

130. See Tuan Nurhafiza, Raja Abdul Aziz & Nor’Adha Abdul Hamid, *The Settlement of Disputes Through Online Dispute Resolution (ODR): A Literature Review*, 2 ASIAN J. RSCH. BUS. & MGMT. 90, 91 (2020) (discussing an online form of internal dispute resolution facilitated by technology).

131. There is an active debate in the literature about the prevalence and meaning of preferential treatment to active consumers (nudniks) in these systems. Compare Arbel & Shapira, *supra* note 62, at 929–31 (2020), with Meirav Furth-Matzkin, *The Distributive Impacts of Nudnik-based Activism*, 74 VAND. L. REV. EN BANC 469, 471–72 (2021); Shmuel I. Becher & Tal Z. Zarsky, *Minding the Gap*, 51 CONN. L. REV. 69, 90–91 (2018); Amy J. Schmitz, *Access to Consumer Remedies in the Squeaky Wheel System*, 39 PEPP. L. REV. 279, 280 (2012).

132. See *supra* Part II.

to a driver waving at another to give them the right of way and then crashing into them. This provides another mechanism of dispute resolution.

Contract interpretation is an adjacent issue. A breach presupposes the existence of an obligation that was not met, which requires us to first define the scope of contractual obligations. For digital contracts, interpreting intent may seem challenging. This issue was repeatedly raised in the context of smart readers.¹³³ Indeed, ascribing meaning to code looks difficult.¹³⁴

Fortunately, Shaanan Cohney, David Hoffman, and Greg Klass have convincingly resolved the interpretive question.¹³⁵ Interpreting digital contracts requires the same toolset that the common law has always used. Importantly, as scale falls, the scope of transactional complexity falls superlinearly.¹³⁶ The room for disagreements in a merger agreement is vastly larger than it is when buying a Coke from a vending machine. Small transactions, small disagreements.

The discussion underlies my view that these tiny agreements are real contracts, rather than pure transactions. However, as noted, the boundaries are quite murky at this scale, and it is understandable that others might hold a more transactional view.

Enforcement. Winning a judgment is not enough; one must also collect it. One of the most challenging issues in macro contracts is the problem that defendants are often judgment-proof (or can deliberately become so).¹³⁷ As the stakes fall, this problem trends to zero,¹³⁸ but a new one appears in its stead: costs of collection can easily become prohibitive. Filing a lawsuit with a small claims court costs \$15 to \$20 in New York,¹³⁹ \$40 in Massachusetts,¹⁴⁰ and \$85 in Alabama.¹⁴¹

133. See Cohney & Hoffman, *supra* note 87, at 324–27 (explaining that judges “may not be able to hypothesize a reasonable human’s interpretation of a given smart contract” given the technology’s complexity).

134. See Frank Pasquale, *A Rule of Persons, Not Machines: The Limits of Legal Automation*, 87 GEO. WASH. L. REV. 1, 1 (2019) (arguing that forms of legal automation can undermine the legitimacy of the law). I hedge this statement because, as we have learned from the emergence of large language models, AI can provide intelligible explanations. See generally Yonathan A. Arbel & Samuel Becher, *Contracts in the Age of Smart Readers*, 90 GEO. WASH. L. REV. 83, 95 (2022) (showcasing the utility of LLMs in simplifying legal texts).

135. See Cohney & Hoffman, *supra* note 87; Klass, *supra* note 85.

136. Ambiguity is embedded within every transaction, but one source of ambiguity comes from the interaction of different transactional terms. Since very new terms can interact with all previous terms, deal complexity increases the scope of potential ambiguities superlinearly.

137. See, e.g., Yonathan A. Arbel, *Asset Shielding and the Theory of Credit*, 48 INT’L REV. L. & ECON. 26, 27–28 (2016) (discussing the use of asset protection to avoid liability).

138. See *id.* at 30–32.

139. *Court Fees in the New York City Civil Court*, NYCOURTS.GOV, <https://nycourts.gov/courts/nyc/civil/fees.shtml> [<https://perma.cc/RWB7-ZH6S>].

This alone could swamp any value from winning a judgment on a nano contract.

In micro contracts, there are at least four solutions to this problem. First is the use of platforms. The platform has deep pockets and is responsible for residual claims against parties on the platform.¹⁴² More importantly, the platform, as a repeat player, has an incentive to effectively resolve common disputes and compensate disgruntled users even without legal action.¹⁴³ Second is the use of reputation. Even if collection is expensive, imposing a sanction in the form of a reputation hit is not. Third is the use of precautions.¹⁴⁴ Platforms typically do not pay drivers until after the trip is finished, but they charge the passenger in real time.¹⁴⁵ The concern that a passenger will not pay is thus largely resolved. The fourth solution is escrow, a solution that can easily be easily implemented by platform-free protocols. By depositing payments in an escrow, and making the release of payment conditional on performance, many enforcement problems are resolved. In smart contracts, the blockchain manages the escrow.¹⁴⁶ But this is far from a foolproof solution.¹⁴⁷ One must still determine whether a party actually performed according to the proper interpretation of the contract. Doing that accurately requires discretion.¹⁴⁸

140. *Small Claims Court*, MASS.GOV, <https://www.mass.gov/service-details/small-claims-court> [<https://perma.cc/D2HK-KRRH>].

141. *Small Claims*, TWENTY-SIXTH JUD. CIR. CT. OF ALA., <https://russell.alacourt.gov/small-claims/> [<https://perma.cc/6BMA-QQ63>].

142. See, e.g., *What Is the Average Uber Accident Settlement?*, LAW PLACE, <https://www.thelawplace.com/faqs/average-uber-accident-settlement/>

[<https://perma.cc/6U22-2AE8>] (noting that victims of Uber accidents have access to settlements resulting from the following damages: property damage, medical bills, loss of income, pain and suffering, and wrongful death).

143. On the incentive of repeat sellers to go beyond the letter of the contract in consumer markets, see Lucian A. Bebchuk & Richard A. Posner, *One-Sided Contracts in Competitive Consumer Markets*, 104 MICH. L. REV. 827, 827–28 (2006); Becher & Zarsky, *supra* note 131, at 90–91 (2018); Arbel & Shapira, *supra* note 62, at 943–44 (2020).

144. Platforms are also incentivized to audit service providers prior to transactions, as recently studied by Xinyu Hua & Kathryn E. Spier, *Holding Platforms Liable* 3 (HKUST Research Paper No. 2021-048, 2023), https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3985066 [<https://perma.cc/CL7N-BM5N>].

145. See, e.g., *Getting Paid*, LYFT, <https://help.lyft.com/hc/e/all/articles/9328619602-getting-paid> [<https://perma.cc/F2MM-85MD>] (announcing a policy of paying drivers every Tuesday, in arrears, for last week’s earnings). For rider charges, see *Pending Charges*, LYFT, <https://help.lyft.com/hc/e/all/articles/115012926167> [<https://perma.cc/7W84-RTKL>].

146. See Farshad Ghodoosi, *Contracting in the Age of Smart Contracts*, 96 WASH. L. REV. 51, 70 (2021) (explaining that smart contracts “create a digital escrow where funds can only be released if certain conditions (performance) are satisfied by the offeree”).

147. Cohny & Hoffman, *supra* note 87, at 385 (“At the bottom, legal scholarship about computable contracts simply hasn’t fully grappled with the irreducibly buggy nature of coding. Errors in coded exchange will result in the parties’ outcomes stubbornly failing to match their goals.”).

148. *Id.* at 386 (“[B]ecause it is imperfect, code-mediated transactions will often fail to achieve what their promisors intend, even as they are surrounded by communications in

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The analysis presented in this Part explains the primary institutional features that underlie nano contracts and exposes some of the ways policymaking can further their adoption. On this basis, we now move to explore how nano contracts can transform several central areas of law: queues, property, employment, and torts. The crux of the analysis will focus on the regulation of queues, an area in which we can easily see nano contracts' transformative effects and failure modes. This will allow us to offer a broader sketch of the issues inherent to other domains of private law. After describing nano contracts' potential, the discussion evaluates risks, as well as whether legal intervention is needed and in which form.

IV. NANO LINES

A. Nano Contracts and the Problem of Queues

Lines are a painful, if often neglected, public policy problem.¹⁴⁹ They emerge whenever demand outstrips service capacity.¹⁵⁰ Busy intersections, doctor's offices, concert ticket booths, amusement parks, customer service call lines, plane boarding, fast food drive-throughs, bank tellers, a plane on the tarmac, and the DMV, are frustratingly common examples. Lines are often a conflict zone; a common source of friction that every so often erupts into wanton displays of violence,¹⁵¹ such as in Black Friday sales or road rage on congested roads.¹⁵² But even in their more quotidian form, lines exact a toll on our lives. At the DMV alone, Americans wait an average of forty-four

'real' languages, intended to be relied on by real people. In such cases, law will confront — and must surmount — two temptations: ignoring the code altogether as a mere instrument of performance or enforcing it as an exculpatory clause written in ciphered text.”)

149. For a comprehensive analysis, see Pery & Zarsky, *supra* note 33, at 1596–97.

150. See David Fagundes, *The Social Norms of Waiting in Line*, 42 L. & SOC. INQUIRY 1179, 1179 (2017). As Fagundes notes, the form of the lines is highly culturally dependent. *Id.* at 1187–88.

151. See Adrian Furnham, Luke Treglown & George Horne, *The Psychology of Queuing*, 11 PSYCH. 480, 480–81, 487 (2020) (reviewing the psychological effect of “queue rage,” and presenting a 2019 study measuring levels of violence caused by customers waiting for treatment at an Israeli hospital).

152. See Tiffany Hsu, *Fistfights and Long Lines on Black Friday? Not as Much Anymore*, N.Y. TIMES (Nov. 23, 2018), <https://www.nytimes.com/2018/11/23/business/black-friday-history.html> [<https://perma.cc/3FHU-5QNM>]; Mark Asbridge, Reginald G. Smart & Robert E. Mann, *Can We Prevent Road Rage?*, 7 TRAUMA, VIOLENCE & ABUSE 109, 109–11 (2006).

minutes per visit.¹⁵³ One study estimated that Americans squander \$10.3 billion annually waiting to see their physician or dentist.¹⁵⁴ Another study estimated that traffic congestion cost Americans over \$7.7 billion in 2019.¹⁵⁵ This is time that could be used for family, recreation, work, hobbies, or romance — but is instead spent waiting in line.

Most lines today are not regulated. “No federal law specifies line protocol or imposes penalties for cutting in”;¹⁵⁶ instead, the line is often “a system of informal social order.”¹⁵⁷ But to say that the line is subject to social norms does not mean that these norms are prosocial. Indeed, David Fagundes describes how the nuanced rules of lines are often accompanied by a shadow threat of social opprobrium that sometimes erupts into violence.¹⁵⁸

Yoram Barzel’s theory of lines and their cost also helps frame our discussion.¹⁵⁹ Normally, markets allocate scarce resources based on a price system, using a system of willingness-to-pay (“WtP”). Lines, instead, allocate resources to those who wait, thus substituting the WtP with a mechanism that Barzel describes as willingness-to-wait (“WtW”).¹⁶⁰ When deciding whether to join a line, an individual assesses whether the waiting is worth her time. Depending on the length of the line, some will join, others will not. As a result, a vicious dynamic emerges. Lines will tend to build up until they suck up so much time that they are hardly worth the wait.¹⁶¹ We confirm Barzel’s theory for ourselves every time we balk at a line that is too long.

Another problem with lines is how they distribute resources. Most lines adopt an allocation rule (known as “queue discipline”) consisting

153. Neel Padmanabhan, *Reducing DMV Wait Times with Queue Management and Digital Transformation*, VIRTUAQ (Mar. 2, 2020), <https://virtuaq.com/blog/2019-03-02-dmv-wait-times> [https://perma.cc/8CUS-7LVA].

154. Akbar Marvasti, *A Contingent Valuation of Customer Delay in Medical Services*, 32 E. ECON. J. 31, 41 (2006).

155. DAVID SCHRANK, LUKE ALBERT, BILL EISELE & TIM LOMAX, 2021 URBAN MOBILITY REPORT 42 (2021).

156. Fagundes, *supra* note 150, at 1179.

157. *Id.* Fagundes later qualifies this statement, noting that in specific instances such as traffic, line cutting can be sanctioned. *Id.* at 1180.

158. *See id.* at 1183–86. Line priority is created by the continued possession of a place in line and, subject to some exceptions, is abandoned if one needs to rest her feet in a more comfortable sitting place. *See also* Gad Allon & Eran Hanany, *Cutting in Line: Social Norms in Queues*, 58 MGMT. SCI. 493, 493–95 (discussing social norms of exception governance).

159. Yoram Barzel, *A Theory of Rationing by Waiting*, 17 J.L. & ECON. 73, 94–95 (1974).

160. *Id.* at 73. It should be noted that “WtW” is my term, not his.

161. *See id.* at 74 (arguing that, when accounting for the cost of waiting, the “consumer’s surplus” from the goods allocated by a queue “is zero,” if the market is to clear).

of first in time wins.¹⁶² Distributing scarce resources based on who happens to be first in time may meet some formal criterion of fairness but is neither equitable nor efficient. Insisting on keeping one's seat on the bus when an individual in need boards, citing "I was here first," evinces egoism rather than care. Recognizing that first in line heuristics are a crude mechanism of allocation, some services offer line refinement in the form of "priority schemes."¹⁶³ For example, on trains, first to come heuristics generally determine who sits first. However, a preference is given to people with certain conditions such as a physical handicap or old age. Some queues use human discretion, i.e., triage, to allocate priority.¹⁶⁴ At the doctor's office, for example, people wait according to the scheduled appointment time. But the staff is given the discretion to give priority to a patient who suffered acute trauma. In specific cases, social status is used to award priority — hence the existence of VIP lines.

Some scholars express hope that we can solve the problem of waiting in line now that online queues are an option.¹⁶⁵ Barzel's theory helps us understand why this is not quite true. Online lines do nothing to produce any excess service capacity and so the resource in question is just as limited as it originally was. We still must bide our time until the specialist is available to see us, our cortado is brewed, and the mechanic gets to our car. True, it is less painful to wait at home than it is to wait at the post office, but this sometimes, quite counterintuitively, worsens the problem. Once lines abandon the implicit cost of standing in line, they lose the signal inherent to the WtW mechanism. When that happens, many more individuals join the line, some of them with a fleeting interest in the product, some with none

162. See JOHN F. SHORTLE, JAMES M. THOMPSON, DONALD GROSS & CARL M. HARRIS, *FUNDAMENTALS OF QUEUEING THEORY* 5–6 (5th ed. 2018) ("A common discipline in everyday life is first come, first served"); Perry & Zarsky, *supra* note 33, at 1596.

163. SHORTLE ET AL., *supra* note 162, at 6. Some restaurants offer the option to order online and suggest that by doing so, one can skip the line. See, e.g., *Mobile Order and Pay*, MCDONALD'S, <https://www.mcdonalds.com/us/en-us/mobile-order-and-pay.html> [<https://perma.cc/3VNJ-4BH3>]. This is not precisely true, as the patron skips one line (ordering) but still must face the other (production). In the event of excess demand, online orders simply turn into a place in line for production (rather than ordering).

164. Those who wait in line also perform some triage, as they may allow people in need to cut in front of them. On the efficiency and limitations of line triage, see Allon & Hanany, *supra* note 158, at 503.

165. See Ramsi A. Woodcock, *The Efficient Queue and the Case Against Dynamic Pricing*, 105 IOWA L. REV. 1759, 1797 (2020) ("[I]n the information age the burden of queuing has been driven almost to zero, because now waiting on line takes only the time needed to log into a website and check to see whether a product is available."); Fagundes, *supra* note 150, at 1191 (noting that online ordering systems "allow circumvention of lines altogether. They enable customers to preorder . . . and pick . . . up from an express counter"). Fagundes, importantly, recognizes the possibility of queue markets enabled by technology. See Fagundes, *supra* note 150, at 1191.

at all. Some are scalpers and others are bots — all of them inflate the line and distort its desired allocation.¹⁶⁶ Relative to a world where those in need could ensure allocation by waiting in a physical line, an online queue can make matters worse. Absent some credible signal of need or merit, online queues are assured to be neither more fair nor more efficient.

Even though the line system is hard to justify on grounds of equity or efficiency, the status quo proves recalcitrant. This is due to twin fundamental problems, which we can dub the verification and the grasshopper problems.

The verification problem arises from the question: how can you tell whether someone in the fast lane is indeed in an urgent situation? Many people would claim a special need just to avoid a line. Thus, it might be necessary to install a costly verifier — like a triage nurse at the emergency room — to make judgments. To solve the problem, hospitals must now employ a full-time health practitioner who spends their expertise on administration rather than care. Another type of cost is the verification process itself.¹⁶⁷ Patients may need to produce documents showing bloodwork, special medical conditions, or urgency. And, at the risk of infinite regress, there will often be a line to the triage itself, as visitors to the emergency room know. Then, there is the cost of the mistakes the verifiers are bound to make in good faith — and we are not assured of that good faith. Given the discretion necessarily allotted to verifiers, some of them abuse their position to give priority to those who “have an in” with them. In the shadow of all of this, we sometimes see the emergence of a new wasteful dynamic, where people learn how to game the verifier. In the organ transplant context, some doctors exaggerate their patients’ needs so that the system will give their patients priority in line (at the expense of the less fortunate patients who remain to languish in line).¹⁶⁸

166. Taylor Lyles, *Bots Are Ruining Your Chance of Buying a PS5 and Xbox Series This Holiday*, IGN (Nov. 15, 2021, 4:18 PM), <https://www.ign.com/articles/bots-scalpers-ruining-chances-of-getting-ps5-xbox-series-x-nintendo-switch-oled> [<https://perma.cc/ETZ6-LYM6>] (“Scalpers have also taken the opportunity to use bots to try and jack up the price of highly desirable and hard-to-find items.”).

167. One study of the cost-effectiveness of triage, accounting for the costs of administration, found an increase in total costs. Stefan Morreel, Ines Homburg, Hilde Philips, Diana De Graeve, Koenraad G. Monsieur, Jasmine Meysman et al., *Cost Effects of Nurse Led Triage at an Emergency Department with the Advice to Consult the Adjacent General Practice Cooperative for Low-Risk Patients, a Cluster Randomized Trial*, 126 HEALTH POL’Y 980, 985 (2022).

168. See Benjamin J. McMichael, *Stealing Organs?*, 97 IND. L.J. 135, 154 (2022) (citing Aaron Ahearn, *Ethical Dilemmas in Liver Transplant Organ Allocation: Is it Time for a New Mathematical Model?*, 18 AM. MED. ASS’N J. ETHICS 126, 126 (2016) (“Essentially, transplant professionals were escalating the level of care pretransplant patients were receiving in order to exaggerate their patients’ illness acuity and move their patients ‘up’ the wait-list.”).

Even when we can resolve the verification problem reasonably well, we are exposed to a second-order problem: the grasshopper problem. While many of us are Aesop's "ants," in the sense of planning for the future, others are carefree "grasshoppers."¹⁶⁹ A person I know well is a veritable grasshopper, and he swears by George Stigler's maxim that "if you have never missed a flight, you are spending too much time in airports."¹⁷⁰ He always leaves late for the airport. He will occasionally arrive so late that he is bound to miss his flight — unless, that is, he gets to skip the airport security line. As it turns out, airport personnel will often allow him to do just that, because they attempt to help passengers in a hurry arrive on time.¹⁷¹

What is so troubling about this example is that this is not an example of the failure of the verification system. The verification method works perfectly here. The grasshopper is in a real rush, and the airport verifier is correct to flag him as someone in need. The problem is that by giving the grasshopper priority, the verifier rewards him for his reckless planning at the direct expense of other passengers who are better planners. This points at the general problem with verification systems of triage: they create unintended grasshopper problems that exacerbate the pressure on the already scarce resources.

Nano contracts circumvent this patchwork. They offer a solution to the problem of queues by creating a protocol for parties to directly, quickly, and potentially anonymously, negotiate the allocation of places in the line among themselves.¹⁷² A nano contract can just as easily be used to auction off a place in line at airport security, at a baseball stadium, and at the pharmacy. It can also be used to pay email recipients to afford special attention to one's email, transmit data faster on the Internet, or get priority for technical support. Notably, this trade does not come at anyone's expense. If the person third in line is trading places with the person who is last in line, only the two trading partners are impacted. This places line-trading transactions in the coveted echelon of Pareto improving transactions — deals where at least one person is made better off without harming anyone else. This is because if the compensation offered is too low, or if one does not want to wait any longer, they can refuse the switch. It is also possible, although less likely, that nano contracts would allow a late-comer to jump to the first place in line, pushing everyone else back a

169. AESOP, THE ANTS & THE GRASSHOPPER (1919), <https://read.gov/aesop/052.html> [<https://perma.cc/HD4Z-4MWD>].

170. Jordan Ellenburg, *Be More Productive: Miss Some Flights*, WIRE (Aug. 11, 2014, 11:25 AM), <https://www.wired.co.uk/article/jordan-ellenburg> [<https://perma.cc/2YH9-7A2U>].

171. See Allon & Hanany, *supra* note 158, at 493.

172. For a statement on the positive distributional gains of line trading, see Barzel, *supra* note 159, at 82.

spot, if the late-comer is willing to compensate all line waiters for the added wait.

Quite remarkably, nano contracts simultaneously solve the verification problem *and* the grasshopper problem without the need for costly triage. They solve the verification problem because it is not enough to just say you are in a rush. The user must put their money (or tokens) where their mouth is. The more others need priority, the more one must stake. This verifies that the user truly values priority. The grasshopper problem is similarly resolved. If my tardy friend had to pay based on how many people he jumps in line, he would certainly start planning better. The requirement to pay for priority rewards good planning and moderately sanctions grasshoppers.

Key to this entire system is voluntary trade. Unlike the current system, which imposes an arbitrary line, nano contracts let people have a choice. I can retain my place in line if I am in a hurry, or I can choose to wait a bit longer and be compensated for my time. Especially in settings where transactions are anonymous, we need not worry about coercion or duress any more than we must worry about bullies who cut in line or “the connected,” who are given priority over us. Unlike systems like priority boarding, the compensation goes to us, not to a third-party actor. The four-way stop is illustrative: it allows all cars to quickly determine who will go first, while remitting payments between line participants. Another example is the food delivery service DoorDash. After making the order, the user is given the option to choose a tip for the driver.¹⁷³ Because the driver views the tip before taking the order, this tip can be used to gain priority in the delivery queue.¹⁷⁴

A related advantage is the p2p nature of the nano contract system. Many firms have seized on the inefficiencies of the status quo and commoditized lines.¹⁷⁵ For example, Six Flags sells the place in line of those who arrived first to those willing to pay more.¹⁷⁶ In socialist countries, there are fixers, variably known as “*tolkach*” or “*matchers*,”¹⁷⁷ who offer to get people ahead in line for the right fee.¹⁷⁸ In

173. Doug H., *Delivery Drivers Can See Your Tip! And It Can Get You Faster Service*, RIDESHARING DRIVER, (Mar. 17, 2023), <https://www.ridesharingdriver.com/tipping-faster-delivery> [<https://perma.cc/9MA9-DSLJ>].

174. *Id.*

175. See, e.g., Martin Lewison, *Demand-Based Pricing in the US Theme Park Industry*, 5 INT'L J. LEISURE & TOURISM MKTG. 271, 281 (2017) (finding that fifty-seven percent of parks examined offered a queue product).

176. *Experience Six Flags with Six Flags Plus*, SIX FLAGS, <https://www.sixflags.com/america/store/tickets> [<https://perma.cc/YBS7-9HQ8>].

177. Alena Ledeneva, *Blat and Guanxi: Informal Practices in Russia and China*, 50 COMPAR. STUD. SOC'Y & HIST. 118, 122 (2008) (describing the *tolkach* as “skilled manipulators of people, procedures, and paperwork”); Yaron Zelekha & Simcha Werner, *Fixers as Shadow “Public Servants”: A Case Study of Israel*, 34 INT'L J. PUB. ADMIN. 617, 617–18

the United States, maître d's often accept bribes in the form of "tips" to give preference to certain guests. Concert venues sell VIP tickets for a hefty premium that allow their holder to avoid the line and enter the venue early.¹⁷⁹ Unlike nano contracts, which remit payments to other people in line, these "queue product" transactions provide revenue for the firm. Because lines are a source of revenue, companies like Six Flags may have less incentive to shorten lines. This is a point about the status quo that must be emphasized: Lines are already commercialized, just not in a p2p manner like nano contracts are. "Queue products" are not equitable, fair, or even efficient,¹⁸⁰ resulting in incentives to preserve the lines.¹⁸¹

Critically, a nano contract does not even have to use money. Consider the course priority rules used by the Kellogg School of Management at Northwestern University.¹⁸² Naturally, some courses are in high demand. Standard systems of registration favor those who plan and sign up early, but not necessarily those with greatest interest or need in a particular course. The University decided to implement a queue-auction system. Every student receives 2,000–3,000 token points.¹⁸³ Students bid, with no maximum, on each of their courses according to a set procedure.¹⁸⁴ At the end of the process, a line priority emerges that reflects the students' priorities for different courses.¹⁸⁵ In much the same way, tokens can be allocated for traffic priority or other forms of access.

The very existence of nano contracts would mitigate the risk associated with life's unexpected events. If we ever found ourselves in a real emergency, we could get to our destination sooner, even if a bit poorer. While we would have to pay for priority, at least we could get it when we need it. This presents a great improvement over our congested roads, where all — independent of need, urgency, or medical

(2011) (discussing machers, tramitadores, and pyraveekars). On the etymology of "macher," see *Macher*, MERRIAM-WEBSTER, <https://www.merriam-webster.com/dictionary/macher> [<https://perma.cc/2FW8-YZJ3>].

178. See generally Tara Bêteille, *Fixers in India's Teacher Labor Markets*, 55 ASIAN SURV. 942, 946, 966 (2015) (noting the diverse functions fixers play and their lack of accountability).

179. Neil Shaha, *How the Music Festival VIP Pass Went from Luxury to Basic*, WALL ST. J. (July 26, 2023, 11:05 AM), <https://www.wsj.com/articles/music-festivals-vip-tickets-8771bffb> [<https://perma.cc/P6YD-8BVA>].

180. See generally Allon & Hanany, *supra* note 158, at 494–95 (studying the game theoretical foundations of line inefficiencies related to imperfect monitoring).

181. See Lewison, *supra* note 175, at 281.

182. *Kellogg Course Bidding System Rules*, NORTHWESTERN UNIV., <https://www.kellogg.northwestern.edu/serial/academics/bidding-registration/course-bidding-rules.aspx> [<https://perma.cc/AA9M-WK8D>].

183. *Id.*

184. *Id.*

185. See *id.*

condition — must wait. And as alluded, one would not have to use the system every day to benefit from it. It is enough for one to know of its existence to insure oneself against risks.

If line trading is profitable, it is natural to wonder why we do not see more of it. The answer comes from the enlightening work of Professor Felix Oberholzer-Gee of the Harvard Business School. Oberholzer-Gee sought to examine why “markets for time” rarely exist.¹⁸⁶ To that end, he had ten researchers approach 500 individuals who waited in line for the cafeteria, the train station, and the DMV.¹⁸⁷ Pretending to be in a hurry, the researcher offered to cut in line in exchange for a \$0–\$10 payment.¹⁸⁸

His first finding is consistent with much of the above. The more money offered, the more people were willing to forgo their place in line (from forty-five percent with no payment to seventy-six percent with \$10).¹⁸⁹ However, only a small minority of people agreed to actually take the payment: they simply let the researcher pass them while refusing payment.¹⁹⁰ It seems that most people used the offer of money as a makeshift verification mechanism but were prevented by social norms from actually accepting it. This is why higher amounts yielded better responses, even though they were not collected. The problem, of course, is that when people do not pay, the credibility of payment offers vanishes. This allows those who do not play by the social rules to manipulate others.

Interestingly, Oberholzer-Gee pushed the line a bit too far. He approached some of the people who previously let others cut ahead of them in line a second time.¹⁹¹ He offered them, again, payment to cut ahead.¹⁹² In all cases, he was summarily rebuffed. “[M]ost of them appeared upset, some angry, a few outright hostile, suggesting that it was probably not safe to continue the experiment.”¹⁹³ He thus concluded that the rarity of markets for time lies in the perception that “exchanges in this market are viewed as one-time favors.”¹⁹⁴

While favors have a positive connotation, they obey a much more complex logic. Because trading places in line is viewed as a favor, people act with outright hostility when they feel that their boundaries

186. Felix Oberholzer-Gee, *A Market for Time: Fairness and Efficiency in Waiting Lines*, 59 *KYKLOS* 427, 428 (2006).

187. *Id.* at 432.

188. *Id.* The experiment offered five different treatments corresponding to offers of \$0, \$1, \$3, \$5, and \$10.

189. *Id.* at 434.

190. *Id.* at 436.

191. *Id.* at 438.

192. *Id.*

193. *Id.*

194. *Id.*

are transgressed. And because it is uncomfortable to ask for a favor from a stranger, many of us feel uncomfortable asking others for help, even when we are in a real hurry. At the same time, we are all too familiar with those who do not concern themselves with the opinions of their peers and liberally cut in line.

Nano contracts do much more than facilitate exchange. They create a norm in which asking for priority does not require calling for special favors.¹⁹⁵ They also implement a mechanism that reduces the friction involved in trades for time. This highlights a major contribution of nano contracts: opening up opportunities of mutual interest that are shrouded today by social and transactional frictions.

The overall effect is, of course, nuanced. While this may increase people's willingness to leave late, this is not necessarily a bad outcome. Research shows that when resources are scarce, people prefer systems where those who wait longer receive greater compensation over systems where priority is assigned based on either a system of lottery or surge pricing.¹⁹⁶ If the success of priority access in parks and airplanes is a guide, consumers adjust quickly to such market norms.¹⁹⁷

B. Legal Policy on Nano-Contracting Lines

Nano contracts offer a general solution to lines. In doing so, nano contracts solve significant problems like permitting people in a rush to gain priority, transferring payments to people with greater patience,

195. An unsettled debate is whether conversion of social processes to market processes leads to more or less undesirable behavior. Uri Gneezy and Aldo Rustichini's famous study found that daycare centers saw an uptick in tardiness when they instituted a fine for late arriving parents. Uri Gneezy & Aldo Rustichini, *A Fine Is a Price*, 29 J. LEGAL STUD. 1, 7–8 (2000). For a replication failure, see Cherie Metcalf, Emily A. Satterthwaite, J. Shahar Dillbary & Brock Stoddard, *Is a Fine Still a Price? Replication as Robustness in Empirical Legal Studies*, 63 INT'L REV. L. & ECON. 1, 1 (2020) (finding in two daycare and tax studies that “the introduction of fines causes respondents to reduce non-compliant behaviour,” and fines “do not cause respondents to adjust their concerns about an incomplete contract consistently with Gneezy & Rustichini's theory”). In the current context, the substitution is not between a social norm and price, but two different types of prices (time versus dollars).

196. Charles Raux, Stéphanie Souche & Yves Croissant, *How Fair is Pricing Perceived to Be? An Empirical Study*, 139 PUB. CHOICE 228, 236 (2009) (“Across the different contexts a general ranking of the perception of allocation rules is found, from the fairest to the most unfair: the moral and the compensation rules, then the queuing and the peak pricing with additional supply rules, and finally the peak pricing with constant supply, the administrative and the lottery rules.”).

197. See Gilda Hernandez-Maskivker & Gerard Ryan, *Priority Systems at Theme Parks from the Perspective of Managers and Customers*, TECH. INNOVATION MGMT. REV., Nov. 2016, at 40, 44 (finding that “customers with stronger negative attitudes towards waiting are more likely to want to avoid waiting in queues. In contrast, people with a more positive attitude towards waiting may be more tolerant of queuing in regular lines”).

and avoiding the costs of verifiers and grasshoppers.¹⁹⁸ But the proliferation of nano contracts would also entail a market creep into areas previously governed by social norms.¹⁹⁹ They also engender distributive concerns regarding their effect on those living close to the social margin, alongside other efficiency, political, and ethical concerns. Whether the legal system should regulate nano contracts, or even permit them at all, depends on our evaluations of these potential concerns.

Perhaps the broadest and most sustained critique of line commodification is that offered by Harvard philosopher, Michael Sandel.²⁰⁰ In his book *What Money Can't Buy*, Sandel seeks to defend the separation of lines and markets, advocating for what he calls the “ethic of the queue.”²⁰¹ This moral system holds that allocating goods through lines is desirable in and of itself, at least relative to price mechanisms.²⁰² A central tenet of the queue ethic is the belief that WtW is better than, or at least not clearly worse than, a WtP system. If society wants to allocate resources to those who value them the most, WtP is limited, Sandel argues, because it does not reflect real need but rather the ability to pay for the good in question.²⁰³ He notes, with visible annoyance, how baseball fans who sit in the expensive front rows often come late and leave early, manifesting only passing interest in the game, unlike the other less affluent diehard fans.²⁰⁴ Lines further embody a democratic ethos, he claims, by visibly affirming our equality as we all languish in waiting, regardless of wealth, race, or creed.²⁰⁵ Thus, Sandel finds the queue ethic to be a superior alternative to market mechanisms of allocation.²⁰⁶

As a general argument, Sandel’s critique is unpersuasive. It would require a great feat of line drawing to explain how a market economy that allocates most of its goods through markets and prices suddenly turns unethical when it comes to lines. Sure, markets and prices have their discontents, and there are those who condemn all market transactions as morally suspect. But in a society where it is permissible for dealerships to sell, say, 2023 Subaru Outbacks based on WtP, how can one justify the dissipation of this principle at the line to the deal-

198. See *infra* Section IV.A.

199. See generally Oberholzer-Gee, *supra* note 186, at 440 (noting the social norms that currently govern queuing).

200. See MICHAEL SANDEL, *WHAT MONEY CAN'T BUY: THE MORAL LIMITS OF MARKETS* 28 (2012).

201. See *id.* at 28.

202. See *id.*

203. *Id.* at 17–43.

204. Sandel seems to assume that the point of a front row seat is to see the game rather than being seen as sitting in the front row.

205. See SANDEL, *supra* note 200, at 18.

206. See *id.* at 30–35.

ership? This position is mystifying because lines are downstream of the price system. Lines tend to emerge when goods are being sold at a price that lies below the market clearing price.²⁰⁷ In our society, the manufacturer is generally free to set prices as it sees fit. If it is permissible for Subaru manufacturers and dealers to raise prices until no line exists, and then offer sale prices when they have exhausted the initial pool of buyers, why is it a moral wrong to keep prices low and sell line priority instead?

The commitment to the queue ethic is especially puzzling in a world where firms already commoditize lines as “queue products.”²⁰⁸ Sandel himself notes that “in recent years, selling the right to cut in line has come out of the shadows and become a familiar practice.”²⁰⁹ These products are largely normalized. As Fagundes notes, “while most customers may dislike them, VIP queues do not represent norm violations.”²¹⁰ Perhaps there is an ethical theory that condemns expedited shipping, but that condemnation certainly has not been widely accepted.

It is also not the case that WtW is a better measure of value than WtP. While the comparative literature is not expansive, the existing evidence that suggests that WtP indeed carries a strong signal. One empirical study examined the decision to purchase a priority pass relative to the decision to wait in the normal line.²¹¹ It found that those who pay value priority much more than those who wait in line.²¹² A different study found no correlation between willingness to pay for a shorter line and economic status, which suggests that payments do measure a real difference in valuation.²¹³

The darkest side of the issue is that, from an egalitarian perspective, we must be cautious about championing WtW. There is an assumption that somehow WtW is more progressive than WtP.²¹⁴ The idea seems to be that because our society has inequality in the distribution of material goods, WtW is an equalizing force.

On reflection, this is wrong. To put the point bluntly, we simply do not live in a society where free time is equally divided. This is the

207. See Barzel, *supra* note 159, at 75.

208. See Lewison, *supra* note 175, at 281.

209. SANDEL, *supra* note 200, at 7.

210. Fagundes, *supra* note 150, at 1190.

211. Hernandez-Maskivker & Ryan, *supra* note 197, at 43–44 (finding that “the greater the negative attitude [by theme park customers] towards waiting times, the higher the probability of customers being express pass holders”).

212. See *id.* at 44.

213. See Marvasti, *supra* note 154, at 41.

214. SANDEL, *supra* note 200, at 39 (“The ethic of the queue . . . has an egalitarian appeal. It bids us to ignore privilege, power, and deep pockets.”).

very thrust of Thorstein Veblen’s “leisure class” framework.²¹⁵ A struggling mother of four working a minimum-wage job will not see much benefit from a system that rewards those who can spare the time to wait in line. And, of course, money and time are often fungible, making inequality in one transform into inequality in the other.²¹⁶ For instance, some people hired line waiters, paying them as much as \$6,000, to gain the right to watch the seminal oral argument in the Supreme Court on same-sex marriage.²¹⁷ Even when people wait for themselves, reliance on WtW can be regressive. Lawyers should be especially sensitive to this point: “Research on the welfare system and eviction shows that time requirements create serious obstacles and stress for poor communities.”²¹⁸ A recent study shows that poor tenants face evictions on a large scale because they cannot afford the time involved in public transit to the courthouse.²¹⁹ Even though they are paid less, those with fewer financial resources do not sit on troves of free time.

I want to make a stronger argument. In many situations, nano contracts will be more progressive than the status quo by offering people a meaningful choice. The current system is not inherently beneficial to the economically disadvantaged, and one’s place in line is a matter of institutional familiarity, advanced planning, the capacity and flexibility to execute on those plans, and, of course, luck. Nano contracts mitigate these factors, which often favor those who are well off. People would be able to elect whether they want to retain their place in line, or whether they want to spend a few more minutes idling in exchange for direct compensation. If a person of low means is on their day off and happens to have a bit of extra time, they could leave the post office with a few extra dollars in their pockets. And if they are in a rush, they can just keep their place (or pay a little to get priority).²²⁰

215. See generally THORSTEIN VEBLÉN, *THE THEORY OF THE LEISURE CLASS* (Oxford Univ. Press 2017) (1899) (arguing that those of lower socioeconomic status have less free time than those of higher socioeconomic status).

216. Fagundes, *supra* note 150, at 1190.

217. Robert Barnes, *Supreme Court Tells Lawyers: Stand in Line Yourself. You Can’t Pay Others to Hold a Spot*, WASH. POST (Oct. 6, 2015, 3:32 PM), https://www.washingtonpost.com/politics/courts_law/supreme-court-bar-bans-line-standing-for-hearings/2015/10/06/a309e0e6-6c15-11e5-aa5b-f78a98956699_story.html [<https://perma.cc/BZN9-TQD5>].

218. Ilya Slavinski & Kimberly Spencer-Suarez, *The Price of Poverty: Policy Implications of the Unequal Effects of Monetary Sanctions on the Poor*, 37 J. CONTEMP. CRIM. JUST. 45, 48 (2021).

219. David A. Hoffman & Anton Strezhnev, *Longer Trips to the Court Cause Evictions*, PNAS, Jan. 3, 2023, at 1, 1–2, <https://www.pnas.org/doi/epdf/10.1073/pnas.2210467120> [<https://perma.cc/DD7C-M4CT>].

220. The standard transaction would involve place trading. This means that if the person in fifth place trades places with the person in seventh place, this has no effect on the person in sixth place.

As long as choice is preserved, nano contracts offer a potential improvement over the status quo. By contrast, attempts to maintain the status quo often unwittingly harm those are less well off.²²¹

There may still be a residual concern with a world in which the wealthy tend to be first in line. Indeed, that is already the case under the current system — elite airline members board first, toll roads give priority to those who can afford them, and VIP tickets create a fast track for those who can afford them. Nano contracts, however, offer a way to remedy some of these issues. If we identify a systemic access concern with a specific type of line, it is possible to issue tradable tokens on the platform. We can allocate priority tokens to people on a monthly or annual basis, which can be used in addition to, or instead of, money.²²² This offers another way to target vulnerable parties, which is not possible under the current system.

While I think Sandel's critique fails in general, I do believe that it contains an important kernel and offers some valuable lessons for the regulation of nano contracts. Rather than a blanket objection to commoditized lines, we should be attentive to the type of good that is being allocated. It is one thing to allocate primary resources such as Subaru Outbacks and tickets to baseball games based on WtP; it is quite a different matter to allocate publicly provisioned goods in this way. This is because public provisioning already implies a judgment that market allocation of the underlying good is faulty. Prominent examples where notions of queue ethic may be applicable include the line to the voting booth, kidney transplants, a place in line for the draft or jury duty, fresh water during a natural disaster, waiting for a court to render a judgment, or access to medical resources during a pandemic.²²³

221. Many unhoused people found that they could earn an income without the destabilizing requirement of background checks by serving as line waiters for Supreme Court hearings — that is, until the Supreme Court banned this practice for attorneys. *Visitor's Guide to Oral Argument*, SUP. CT. OF THE UNITED STATES <https://www.supremecourt.gov/visiting/visitorsguidetooralargument.aspx#attny> [<https://perma.cc/G99H-HJ6S>]; see also Barnes, *supra* note 217.

222. The analogy of food stamps, rather than direct money distributions, is apposite. On the two methods, see ROBERT BREUNIG, INDRANEEL DASGUPTA, CRAIG GUNDERSEN & PRASANTA PATTANAIK, U.S. DEP'T OF AGRIC., EXPLAINING THE FOOD STAMP CASH-OUT PUZZLE (2001) (discussing the empirical tendency of households to spend more on food when given food stamps relative to equivalent cash transfers); see also Siobhan McDonough, *Giving People Cash Is Usually Better than Shipping Them Food*, VOX (June 28, 2022, 10:00 AM), <https://www.vox.com/future-perfect/23180175/cash-aid-food-global-africa-famine-hunger> [<https://perma.cc/6U37-4FMQ>].

223. See, e.g., Megan Twohey, Steve Eder & Marc Stein, *Need a Coronavirus Test? Being Rich and Famous May Help*, N.Y. TIMES (Mar. 18, 2020), <https://www.nytimes.com/2020/03/18/us/coronavirus-testing-elite.html> [<https://perma.cc/LDM5-7N89>].

What ties these examples together is that society decided that the goods should be allocated outside of markets.²²⁴ In those cases it will certainly be true that commoditizing the line would undermine this goal. Explicit markets in lines in such instances may be offensive to our sense of equality and justice by expressing the view that some people’s rights, votes, lives, or sufferings are more valuable than those of others. By creating markets in those domains, we risk changing the very nature of the good itself. As Sandel notes, “How a good is allocated may be part of what makes it the kind of good it is.”²²⁵ Another effect is the crowding out of social norms. If an elderly, frail woman asks a person to get ahead in line to the voting booth because she has a doctor’s appointment, social norms dictate the answer to be “sure ma’am,” rather than “that will be \$2.50.”²²⁶

By focusing our attention on these types of goods, we can come to appreciate the need to regulate, and sometimes even ban, nano contracts in certain contexts. The quest for policymakers will be two-fold: (1) identify these contexts, and (2) find measures that can actually work to limit the proliferation of nano contracts. To an extent, legislators have already begun this quest by making it illegal to trade in certain rights.²²⁷ Interestingly, there is no specific sanction for queue trading in the context of public provision of supplies during an emergency, but it is quite likely to be frowned upon.²²⁸

At the same time, it is important to recognize that limiting private contracting, side deals, and shadow bargaining is difficult. As the Oberholzer-Gee study shows, some lines are partly protected from the incursion of markets by social norms.²²⁹ As particular applications of nano contracts can be designed to allow people to trade under the screen of anonymity, compliance with social norms will become a challenge. Therefore, it is important to heed the constraints identified in Section III.B,²³⁰ as the solutions usually involve reliance on broad-

224. See, e.g., Kimberly D. Krawiec, *Markets, Repugnance, and Externalities*, 19 J. INSTITUTIONAL ECON. 944, 944 (2023) (discussing the existence of “repugnant markets” that society seeks to limit).

225. SANDEL, *supra* note 200, at 33.

226. I do not make the argument that our existing social norms function well in general. I submit that even common norms of courtesy suffer from deep pathologies, as explored in Yonathan A. Arbel & Yotam Kaplan, *Tort Reform Through the Backdoor: A Critique of Law and Apologies*, 90 S. CAL. L. REV. 1199, 1220–24 (2016) (discussing, as an example, apologies given after an accident as a mechanism to avoid liability for negligence).

227. See Krawiec, *supra* note 224 (providing examples of the sale of kidneys, military commutations, indulgences, and public office).

228. See, e.g., ALA. CODE § 8-31-3 (2022) (making it unlawful “for any person to impose unconscionable prices for the sale or rental of any commodity or rental facility during the period of a declared state of emergency”).

229. See Oberholzer-Gee, *supra* note 186, at 429.

230. See *supra* Section III.B.

er institutions and regulators may have more success regulating these institutions than the parties themselves.

So far, I have argued that nano contracts have progressive effects and bring social utility. However, despite nano contracts' ability to solve the grasshopper problem, there is one additional efficiency-based concern. This is the problem of "cloggers." Recall the four-way stop example. There, I assumed that those four drivers were already on the road. But nano contracts can also induce more people to go on the road. With nano contracts in place, cloggers may find it profitable to drive aimlessly, in the hope of collecting money from drivers who are in a rush. This would introduce delays to all drivers, increase the cost of travel for drivers in a rush, and waste their own time.

Despite this real possibility, cloggers do not deal a fatal blow to the use of nano contracts to solve queues. This is because cloggers must bear real costs when they engage in clogging. Airlines oversell flight tickets, calculating that some passengers will miss their flights. When flights are overbooked, however, airlines offer handsome payments to people who are willing to forgo their place in line.²³¹ Yet, there is no evidence of widespread abuse by cloggers who strategically book busy flights.

Because of these costs and the relatively modest payments from nano contracts, it is unlikely that clogging will be widespread. Even in the situations where clogging does emerge as a problem, we should consider two responses. One is indifference: a small degree of clogging is tolerable, given that the payments go to people who are quite likely suffering from lack of means, as demonstrated by their engagement in the unpleasurable activity of clogging. The second is the adoption of keyhole solutions, like banning clogging and imposing restrictions on clogging behavior (e.g., cars that drive aimlessly for hours will not be able to collect payments).

In summary, nano contracts offer a natural solution to the problem of queues. Evaluation of their merits suggests that, in most cases, there are real advantages — both ethics- and efficiency-based — to their adoption. True, we need to exercise caution in the case of publicly provisioned goods, as nano contracts can crowd out social norms and corrode the goods themselves. However, for the vast array of products and services, nano contracts offer a significant improvement over the current system. Payments made through nano contracts can

231. U.S. DEP'T OF TRANSP., *BUMPING & OVERSALES* (Apr. 15, 2021), <https://www.transportation.gov/individuals/aviation-consumer-protection/bumping-oversales> [<https://perma.cc/5V4Y-8EPL>] (showing that compensation for passengers who are denied boarding on an overbooked domestic flight runs up to 400 percent of the one-way fare, up to \$1,550).

be progressive, providing people of limited means with another way to monetize a spare moment here and there. Nano contracts also reward planners and waiters, while relieving all of us from anxiety about the future. This is not to say that a hands-off regulatory approach is necessary. Regulatory involvement will be needed for tasks such as issuing tokens and delimiting permissible uses. But, as a general outlook, nano contracts hold important potential for improving the social problem of queues.

V. NANO LEASES

A. *Nano Leases and Excess Capacity*

Most of our personal resources are underutilized. Take the personal household: The average car sits idly for twenty-two hours a day (i.e., ninety-five percent of the time).²³² The average drill is used for twelve minutes a year.²³³ A large percentage of homes are barely used — think of the kitchen, bathroom, and shower, which are only used for a few short hours each day. We wear only one shirt at a time, leaving every other shirt to sit idly for weeks at a time. Even commercial assets have a high degree of downtime. Office space is used only for the workday (and since the COVID-19 pandemic, much less);²³⁴ restaurants normally only operate for half of the day, despite occupying expensive real estate; even factory machines rarely run 24/7.²³⁵ Idle assets account for a sheer amount of waste.

Nano contracts offer a way to utilize this idle capacity through nano leases,²³⁶ approximating Lobel’s vision of “ushering [in] the end of idle capacity.”²³⁷ Consider a working example from a start-up

232. Paul Barter, “Cars Are Parked 95% of the Time.” *Let’s Check!*, REINVENTING PARKING (Feb. 22, 2013), <https://www.reinventingparking.org/2013/02/cars-are-parked-95-of-time-lets-check.html> [<https://perma.cc/3RQ5-SJTV>].

233. Leon Kaye, *Why Sharing Makes Sense in an Over-Consuming World*, GUARDIAN (Jan. 12, 2012, 11:43 PM), <https://www.theguardian.com/sustainable-business/collaborative-consumption-sharing> [<https://perma.cc/9WKZ-JL2Y>].

234. Jose Maria Barrero, Nicholas Bloom & Steven J. Davis, *Why Working from Home Will Stick*, (Nat’l Bureau of Econ. Rsch., Working Paper No. 28731, 2021).

235. The Federal Reserve publishes estimates of industrial capacity utilization which reveal that over twenty percent of industrial capacity goes unutilized. See FED. RESERVE, G.17 (419), STATISTICAL RELEASE: INDUSTRIAL PRODUCTION AND CAPACITY UTILIZATION 19 (2022), <https://www.federalreserve.gov/releases/g17/current/default.htm> [<https://perma.cc/Y5CQ-4YZB>] (“Over the 1972–2022 period, the average total industry utilization rate was 79.7 percent; for manufacturing, the average factory operating rate was 78.2 percent.”).

236. For convenience of exposition, the following analysis groups leases, licenses, and sales under nano contracts. Substantively, the lines between these legal categories become quite murky at the nano level.

237. Lobel, *supra* note 18, at 108.

called Tulerie, which allows people to rent out their clothes for a short duration.²³⁸ Or another from a new start-up called Helium.²³⁹ Most people have underutilized broadband Internet capacity, with median households using only one-third of the capacity used by power users.²⁴⁰ Helium offers people with such excess capacity the option to install a router that grants casual access to passersby who pay for access. The stakes and duration of every transaction are small and short, making them a clear example of a nano contract, or even a nano lease.²⁴¹

The potential of a service like Helium goes far beyond saving on roaming charges in a new city. It opens up the ability for broad coverage for Internet of Things (“IoT”) machines, offering ways for electronic scooters, wearable objects, parking meters, cars, and even dog tags to communicate with the world through direct Internet access.²⁴²

Another impressive example is food sharing. Olio is a popular food-sharing platform that allows businesses to donate excess food to food-insecure individuals.²⁴³ In January 2021, Olio facilitated around 14,000 food exchanges each day.²⁴⁴ While not the same as an individual-to-individual nano lease, the platform is arguably demonstrative of the viability of a marketplace for excess cooking capacity. We might imagine neighbors offering an extra pot of stew, a weekly meal prep, or a fresh-cut salad on demand. Germaphobes might balk, but the indolent and the bon vivant will celebrate.²⁴⁵

238. *How it Works*, TULERIE, <https://tulerie.com/pages/how-it-works> [<https://perma.cc/5Q97-ANYV>].

239. Kevin Roose, *Maybe There’s a Use for Crypto After All*, N.Y. TIMES (Aug. 3, 2022), <https://www.nytimes.com/2022/02/06/technology/helium-cryptocurrency-uses.html> [<https://perma.cc/54SM-37RW>].

240. *Broadband Insights Report (OVBI)*, OPENVAULT, (2021), https://openvault.com/wp-content/uploads/2022/03/OVBI_4Q21_Report_FINAL-1.pdf [<https://perma.cc/EW3N-47QN>].

241. One user reports earning about \$1 a day from such nano leases in Harrisburg, Pennsylvania. Robbie Paul, *What is Helium and How Does it Work?*, HELIUM (July 20, 2021), <https://www.digikey.bg/en/blog/what-is-helium-and-how-does-it-work> [<https://perma.cc/LD3A-5EUX>].

242. Helium, *What’s Helium? Glad You Asked.*, YOUTUBE, (Nov. 7, 2019), <https://www.youtube.com/watch?v=Vx9YyS7-d3g> [<https://perma.cc/7D5N-FYEC>].

243. *Share More, Waste Less*, OLIO, <https://olioapp.com/en/> [<https://perma.cc/L4YQ-LHT9>].

244. Tamar Makov, Tamar Meshulam, Mehmet Cansoy, Alon Shepon & Juliet B. Schor, *Digital Food Sharing and Food Insecurity in the COVID-19 Era*, RES. CONSERVATION & RECYCLING, Feb. 2023, at 1, 4 fig.1.

245. There is already a secretive network of gourmet home cooking in various countries. See, e.g., Nicholas Jordan, *Under the Table: Australia’s Dazzlingly Diverse Home Cooking Underground*, GUARDIAN, (Oct. 10, 2021, 12:30 PM), <https://www.theguardian.com/food/2021/oct/11/under-the-table-australias-dazzlingly-diverse-home-cooking-underground> [<https://perma.cc/WTR7-2U5S>].

A last illustration is something most of us would not even consider to be capacity: aerial passage rights over land. It is quite clear that drones will become an increasingly important mode of goods delivery, but their success depends on the ability to pass over land without violating the aerial rights of landowners on their delivery path.²⁴⁶ The issue is highly contentious, and the drone industry tries to promote legislation that would extinguish landowners' rights to exclude drones from their low airspace.²⁴⁷ Nano contracts offer an alternative solution: if drones can directly negotiate, in real time, with landowners, they can offer a consensual form which respects homeowners' rights without blocking new technology.²⁴⁸

Beyond these examples, many assets owned by individuals can be converted to use nano leases. Used books, garage-stored bikes, PC computing power, right of way through their backyard, video games, a mailbox address, extra closet space, access to the yard water hose, garage access, fruit trees, and muscadine vines. Once transaction costs are low enough, the options appear unlimited.

A few substantive caveats are in order. First, some physical costs and limitations impede nano leases. A lawn mower, to use an example raised in the literature, still needs to be transported from yard to yard. And given high demand during the weekends, lawn mowers may not be perfectly susceptible to sharing.²⁴⁹ Some degree of idleness is inevitable, even with ideal nano contracts. Second, dispute costs can arise whenever a person returns the lawnmower broken, downloads illegal materials using our IP address, or commits the cardinal sin of putting a dog ear in our book. Third, and more deeply, not all underutilization is wasteful. As Fennell elucidates, “the periodic idleness of seemingly redundant assets does not necessarily bespeak inefficiency.”²⁵⁰ There is more to an asset than its utilization. It might be narrowly more efficient to have someone wear my shirt when I'm not wearing it, but not having unique access to it will disrupt something very basic about how I perceive myself in relation to my property — not to mention questions of hygiene. Peggy Radin's work goes to the heart of the matter when she writes how certain objects we possess are “closely [tied] up with [our] personhood because they are part of the way we constitute ourselves as continuing personal entities in the world.”²⁵¹

246. See Hillary B. Farber, *Keep Out! The Efficacy of Trespass, Nuisance and Privacy Torts as Applied to Drones*, 33 GA. ST. U. L. REV. 359, 367–79 (2017).

247. See Troy A. Rule, *Drones, Airspace, and the Sharing Economy*, OHIO ST. L.J. 158, 159 (2022).

248. For a platform-based solution, see *id.* at 172.

249. See FENNELL, *supra* note 20, at 143–44; Lobel, *supra* note 18, at 110.

250. FENNELL, *supra* note 20, at 143.

251. Margaret Jane Radin, *Property and Personhood*, 34 STAN. L. REV. 957, 959 (1982).

My grandfather's old pipe is a source of value to me, even though it is never utilized.

We want to be sympathetic to these arguments, but also avoid stretching them too far. For many assets and many individuals, the reason why assets are not shared with others has little to do with autonomy, ownership, or necessary slack, and probably more to do with the transaction costs involved in sharing them. The gig economy has shown that, once transaction costs are tamed, many people are happy to let strangers use their private homes,²⁵² drive their cars,²⁵³ share their parking space,²⁵⁴ and even provide excess storage room in their closet.²⁵⁵ People see the tradeoffs in their lives differently than we do, and respecting those choices is part of respecting their autonomy.

The benefits of nano leases go beyond putting idle capacity to use.²⁵⁶ To lessors, monetizing underutilized assets can be an important source of income and help defray bills, while freeing up space. Nano leasing can improve household liquidity, a deep concern that affects low-income households with particular force.²⁵⁷

To lessees, the availability of nano leases makes it less necessary to own, license, or rent goods in the first place.²⁵⁸ For example, knowing that we can reliably access a laptop on demand can make it less necessary to travel with one. Leasing also has the advantage of allowing specialization. Owning one's own bandwidth connection involves research into the following: conducting market analysis for providers, selecting the correct router, identifying the optimal transmission

252. Rawson, *supra* note 67.

253. *How Turo Works*, TURO, <https://turo.com/us/en/car-rental/united-states> [<https://perma.cc/C923-ZVHU>].

254. *How SpotHero Works*, SPOTHERO, <https://spothero.com/faq> [<https://perma.cc/ECV6-7B7N>].

255. Sarah Holder, *The Airbnb for America's Extra Crap Is Here*, BLOOMBERG (July 13, 2019), <https://www.bloomberg.com/news/articles/2019-07-03/rent-out-your-closet-with-an-airbnb-for-storage> [<https://perma.cc/WRN2-TTEH>].

256. See generally Thomas Merrill, *The Economics of Leasing*, 12 J. LEGAL ANALYSIS 1, 1 (2020) (highlighting benefits of leasing such as allowing owners to finance purchases, minimizing some ownership risks, and reducing transaction costs).

257. On positive household liquidity effects of house-sharing, see Jinan Lin, Tingting Nian & Vijay Gurbaxani, *Impacts of the Sharing Economy Entry and Regulations on Financial Delinquencies 1* (Apr. 23, 2023) (unpublished manuscript), https://papers.ssrn.com/sol3/papers.cfm?abstract_id=4041490 [<https://perma.cc/U6GT-VQJY>]; Andrew J. Bibler, Keith F. Teltser & Mark J. Tremblay, *Short-Term Rental Platforms and Homeowner Displacement: Evidence from Airbnb Registration Enforcement 27* (Jan. 30, 2023) (unpublished manuscript), https://papers.ssrn.com/sol3/papers.cfm?abstract_id=4390232 [<https://perma.cc/X727-43QG>].

258. In fairness, the research on the relationship between ridesharing app usage and household vehicle ownership finds contradictory and inconclusive effects, suggesting that in some instances people may buy more cars in order to utilize them for commercial reasons. See Yanghao Wang, Wei Shia & Zhenhua Chen, *Impact of Ride-Hailing Usage on Vehicle Ownership in the United States*, 101 TRANSP. RSCH. PART D: TRANSP. & ENV'T, Dec. 2021, at 1, 1.

channel, and updating and sometimes even replacing the firmware. But nano lessees are spared all that trouble: they decide how much they are willing to pay and then just connect. Potential lessors can specialize in providing bandwidth services, letting others enjoy their acquired expertise.

Heralding nano leases is the rise of the XaaS model discussed above.²⁵⁹ Consider, in particular, the model of Product-as-a-Service (“PaaS”).²⁶⁰ Under this model, a firm takes a product that it would normally sell and instead offers it on a pay-per-use or subscription service. For example, Homie offers individuals the ability to treat their washing machines, dryers, and dishwashers as a service for which they pay-per-use, with the company retaining responsibility for maintenance and detergent.²⁶¹ A more familiar example is digital-storage-as-a-service. Local storage was a significant concern before cloud storage, making it necessary for individuals to own a large volume of storage media — disks, CD-ROMs, hard-drives, USBs, and so on. Today, cloud storage has deeply transformed the notion of owning one’s data.²⁶²

Unlike these top-down transactions, nano contracts offer the ability to connect individuals with other individuals in a p2p fashion. This decentralized model has important promise, especially in contexts where spatial concerns are at issue. If Mr. Whiskers slips through the door into the city, we can be sure to locate him using his tags and local Internet networks.²⁶³ Broad access to home laundry and ironing can make travel anywhere much more comfortable. The ability to reliably use my neighbor’s laundry machine will spare me the need to buy a machine or rent a larger apartment. Once a sufficiently broad network of continuous supply is achieved, many other nano leasing opportunities currently covered by the fog of the future will become visible. After all, we can trust that wherever we go we can purchase milk on demand, making it unnecessary to haul a cow with us.²⁶⁴

259. See *supra* notes 74–82 and accompanying text.

260. Tasker O. Generes, Jr., *Get Ready for the Product-As-A-Service Revolution*, FORBES (Oct. 15, 2020, 9:00 AM), <https://www.forbes.com/sites/servicenow/2020/10/15/get-ready-for-the-product-as-a-service-revolution/> [https://perma.cc/2GBM-RTCY].

261. *Subscription on Household Appliances*, HOMIE, <https://www.homiepayperuse.com/en/> [https://perma.cc/YZ57-UQSA].

262. Johan David Michels, Christopher Millard & Srishti Joshi, *Beyond the Clouds Part I: What Cloud Contracts Say About Who Owns and Can Access Your Content 2* (May 11, 2019) (unpublished manuscript), https://papers.ssm.com/sol3/papers.cfm?abstract_id=3386609 [https://perma.cc/ZP4X-Q4YZ].

263. Apple’s AirTags already offer a similar functionality, although the scope of coverage is limited. See Sascha Segan, *Apple AirTag Review*, PCMAG (June 9, 2021), <https://www.pcmag.com/reviews/apple-airtag> [https://perma.cc/UK9S-47P3].

264. See FENNELL, *supra* note 20, at 136.

B. The Legal Policy on Nano Leasing

Nano contracts allow us to better utilize our resources, which challenges our traditional notions of ownership, possession, and renting. The shift from owning things to leasing them, particularly when applied to a wide range of assets, represents a conceptual shift. In the Demsetzian framework, the primary evolution in property regimes takes place between systems of mutual governance to systems of private property.²⁶⁵ Nano contracts suggest that there is another potential move in the folds — from property to contract. We can view nano contracts as an invitation to engage in an important conversation about the social meaning of the transition to a world where governance is dominated by the latter.²⁶⁶ The following discussion briefly outlines some key concerns.

One concern about nano contracts is that their use challenges the concept of private ownership. Under the Hegelian developmental thesis, the ownership of at least some private property “is essential to the development and maintenance of capacities and self-understandings that make up free personality.”²⁶⁷ This raises interesting questions for nano contracts: is something severed when we no longer own basic property? Is the leasing-self different in important ways from the owning-self? What aspects of property are tied up to autonomy: rights to exclude, abilities to break and shape, or the temporal continuity of our relationship to objects we can call our own? Perhaps something profound is lost when our interactions with goods are tentative and time-bound. These are questions that future property scholars will want to debate.

The endowment effect, a cornerstone of behavioral economics and a highly influential idea in legal scholarship, suggests that ownership imbues goods with special meaning.²⁶⁸ In experiments conducted around the world, researchers found that people who own goods value them more highly than they do when given the option to purchase

265. See Harold Demsetz, *Toward a Theory of Property Rights*, 57 AM. ECON. REV. PAPERS & PROC. 347, 356–57 (1967); see also Thomas W. Merrill, *The Demsetz Thesis and the Evolution of Property Rights*, 31 J. LEGAL STUD. S331, S332 (2002).

266. See Merrill, *supra* note 256, at 44.

267. See ALAN PATTEN, *HEGEL’S IDEA OF FREEDOM* 140 (1st ed. 1999).

268. In psychology, see, for example, Daniel Kahneman & Amos Tversky, *Prospect Theory: An Analysis of Decision Under Risk*, 47 ECONOMETRICA 263, 277–78 (1979); Daniel Kahneman, Jack L. Knetsch & Richard H. Thaler, *The Endowment Effect: Evidence of Losses Valued More than Gains*, in THE HANDBOOK OF EXPERIMENTAL ECONOMICS 939, 939–42 (Kenneth J. Arrow & Michael D. Intriligator eds., 1st ed. 2008). In law, see, for example, Russell Korobkin, *Wrestling with the Endowment Effect, or How to Do Law and Economics Without the Coase Theorem*, in THE OXFORD HANDBOOK OF BEHAVIORAL ECONOMICS AND THE LAW 300, 300–334 (Eyal Zamir & Doron Tiechman eds., 2014).

them.²⁶⁹ However, when goods are designated as trade goods, this effect disappears.²⁷⁰ For those who believe in the endowment effect, nano leasing should give pause. It seems that hyper-leasing, either as a lessee or a lessor, could fundamentally alter the value people endow in their property.

There are also consequences for the notion of leasing itself.²⁷¹ For example, Airbnb has not only changed the way people monetize their property rights, but it has also changed the meaning of ownership.²⁷² People who rent their homes on Airbnb often make changes to make the space more inviting, keep it cleaner, and install better amenities.²⁷³ While some of these changes are innocuous, even salutatory, they can also redefine how people think about their homes: from a private sanctuary to a place of business.²⁷⁴

Contrary to what one might expect, the erosion of ownership may be compatible with an array of anti-consumerist, environmentalist, and Marxist philosophies.²⁷⁵ Under these theories, private property and excessive consumption are objectionable. Some of these ideas can be traced back to the work of economist Thorstein Veblen, who argued that conspicuous consumption, fueled by a desire to signal social status, drives consumers to consume in excess.²⁷⁶ The result, as explored by thinkers like Juliet Schor, is an overconsumption that con-

269. For an excellent comprehensive and mordant review, see Kathryn Zeiler, *What Explains Observed Reluctance to Trade? A Comprehensive Literature Review*, in RESEARCH HANDBOOK ON BEHAVIORAL LAW AND ECONOMICS 347, 347–93 (Joshua Teitelbaum & Kathryn Zeiler eds., 2018).

270. *Id.* at 359.

271. An old joke reveals something deeper about the difference between ownership and rental. It goes: “Which vehicle has the best off-road performance? A rental car.”

272. Alexandra J. Ravenelle, *Sharing Economy Workers: Selling, Not Sharing*, 10 CAMBRIDGE J. REGIONS, ECON. & SOC’Y, 281, 289–90 (2017) (offering an insight into sharing economy workers’ self-perception). Many do not see themselves as entrepreneurs, but rather just as hustlers. *Id.* at 288–92. Some, however, leverage their business into a growth strategy. *Id.*

273. The Reddit subcommunity r/AirBnB contains various posts of users seeking to “spruce up” their home in preparing it for Airbnb rentals. See, e.g., u/flackahino, *Hi Reddit! What Are Some Ways I Can Make My Listing/Place More Attractive? Also, as is, What Would Yall Rank It 1-10? 10 Being Best*, REDDIT (Oct. 26, 2017, 11:54 AM), https://www.reddit.com/r/AirBnB/comments/78wgyg/hi_reddit_what_are_some_ways_i_can_make_my/ [<https://perma.cc/L7RU-9THB>].

274. See generally Rodrigo Saturnino & Helena Sousa, *Hosting as a Lifestyle: The Case of Airbnb Digital Platform and Lisbon Hosts*, 12 PARTECIPAZIONE E CONFLITTO 794, 810–12 (2019) (discussing the transformation of the “ontological home” from a place of respite to a place of business).

275. For a broad, critical review of the anti-consumerism movement, see Katerina Makri, Bodo B. Shlegelmilch, Robert Mai & Katharina Dinhof, *What We Know About Anticonsumption: An Attempt to Nail Jelly to the Wall*, 37 PSYCH. & MKTG. 177, 177 (2020).

276. VEBLEN, *supra* note 215, at 69.

tributes to environmental degradation.²⁷⁷ One solution advocated by these movements is the sharing of resources among members and the removal of the stigma around owning few items. Communal living arrangements, such as the family, private clubs, and Moshavim and Kibbutzim, all exemplify models of shared property governance.²⁷⁸ Nano contracts involve a profit motive and can lead to concentration of capital, so they are by no means equivalent to these arrangements. Nevertheless, they may also address concerns with private property and waste. Nano contracts allow multiple people to share the same goods and thereby considerably reduce private ownership. The greater utilization of assets would reduce the need to overproduce items like drills and tractors, mitigating the toll on the environment. To the individual, nano contracts could offer a roadmap to a self that is not anchored by the need to own. Life-as-a-service, if you will.

Jurisprudentially, nano contracts could also have a disruptive effect, going to the very heart of the legal notion of property. As Henry Smith explains, property is an architecture — a system, rather than the collection of isolated functions implied by the metaphor of the easily separable bundle of sticks. As Smith argues, property is, first and foremost, about the ability to put assets to use,²⁷⁹ with other features (e.g., exclusion rights and leasing rights) emerging only as means to this end.²⁸⁰ Accordingly, many of the features of property law are contingent. For example, the right to exclude is not an inherent aspect of property, but an attempt to solve a problem of transaction (or, more specifically, information) costs. Thus, “[i]n a zero transaction cost world we could use all governance all the time, whether supplied by government or through super-fine grained contracting among all the concerned parties.”²⁸¹ Nano contracts arise from asymptotically low transaction costs between a large mass of users. Thus, they offer the ability to develop radically different governance mechanisms, far more fine-tuned than crude notions of monopoly governance implied by today’s property regimes.

Contracts do not go unscathed either. Nano leases straddle sales, leases, and licenses, and thus present a difficult question of classification. For Article 2 of the Uniform Commercial Code (“U.C.C.”) to

277. JULIET B. SCHOR, *THE OVERSPENT AMERICAN: UPSCALING, DOWNSCALING, AND THE NEW CONSUMER* 156 (1st ed. 1998).

278. See Richard D. Schwartz, *Social Factors in the Development of Legal Control: A Case Study of Two Israeli Settlements*, 63 *YALE L.J.* 471, 474–75 (1954).

279. Henry E. Smith, *Property Is Not Just a Bundle of Rights*, 8 *ECON. J. WATCH* 279, 281 (2011) (arguing that “ends in property [including the right to exclude] relate to our true interests served by property: interests in using things”).

280. *Id.* (“Property serves purposes related to use by employing a variety of delineation strategies.”).

281. *Id.* at 282.

apply, the contract must involve a sale of goods, which means the passing of title.²⁸² While this may be true of some nano contracts, Article 2 of the U.C.C. will not apply to, say, bandwidth access agreements. Further, the transactional scale of nano contracts makes Article 2's overall regulatory approach far less appealing. Unlike sellers of heavy equipment, it makes little sense to offer parties to nano leases extensive inspection rights or rights to insist on perfect tender rules.²⁸³ These rights become increasingly less applicable when the scale is as small as someone who is licensing picking rights from their prolific mulberry tree.

Some transactions may be thought of as nano leases, thus controlled by U.C.C. Article 2A.²⁸⁴ However, at this scale, leases become hard to distinguish from licenses. The proper classification has great practical significance, as it affects matters such as jurisdiction, termination rights, and the availability of self-remedies. Under 2A-103(J), a lease involves the transfer of possession,²⁸⁵ but a transfer of possession is also consistent with a license. To distinguish the two, courts find licenses for non-exclusive grants of possession,²⁸⁶ revocable agreements,²⁸⁷ and when the agreement's scope is limited to in personam rights (although this latter examination often appears conclusory).²⁸⁸ The problem is that an extremely short extension of possession is often indistinguishable from exclusive possession, and revocation at these time scales is often irrelevant. Thus, when a nano contract provides a person with fleeting access to another's jumper cables, these issues become extremely hard to disentangle.

In terms of policy, one major concern with nano contracts for excess capacity is distributional. Take the case of broadband. As noted,

282. The Uniform Commercial Code defines a "sale" as "the passing of title from the seller to the buyer for a price." U.C.C. § 2-401 (AM. L. INST. & UNIF. L. COMM'N 1977).

283. *Id.* § 2-513 (providing inspection rights and a right to reimbursement for inspection costs if the goods fail to conform and are rejected).

284. *Id.* § 2A.

285. *Id.* § 2A-103(J).

286. See *In re Caribbean Petrol. Corp.*, 444 B.R. 263, 270-71 (Bankr. D. Del. 2010); *Gage v. City of Topeka*, 468 P.2d 232, 232 (1970); *Jetz Serv. Co. v. AGS Meadow Oaks Assocs.*, No. 92 CIV. 4439, 1993 WL 17201, at *2 (S.D.N.Y. Jan. 14, 1993); *United States v. Anderson Cnty., Tenn.*, 575 F. Supp. 574, 578 (E.D. Tenn. 1983), *aff'd*, 761 F.2d 1169 (6th Cir. 1985); cf. *Spinks v. Equity Residential Briarwood Apartments*, 90 Cal. Rptr. 3d 453, 482 (6th Dist. 2009).

287. See, e.g., *N. Alaska Env't Ctr. v. State Dep't of Nat. Res.*, 2 P.3d 629, 639 n.23 (Alaska 2000) ("A permit to use land revocable at the will of the grantor is generally considered a license.").

288. *Joplin Supply Co. v. West*, 130 S.W. 156, 161 (Mo. App. Ct. 1910) ("There is a marked difference between a license and a lease. Under a lease, the right of possession against the world is given to the tenant, while a license creates no interest in the land, but is simply an authority or power to use in some specific way.").

most users underutilize their capacity.²⁸⁹ As a result, broadband suppliers can offer better pricing, factoring in actual average usage rates. If certain home users start commercializing their excess capacity, actual usage will rise, increasing service costs for the providers. It is likely that costs will rise, not only for those who nano lease access, but for everyone. This cross subsidy creates unfairness between consumers. There are instances where increased capacity has broader and less obvious effects. In an apartment building, it matters whether an apartment is utilized by a single person or revolving strangers. Not necessarily because of the apartment space capacity itself, but because of greater utilization of shared resources such as elevators, a sense of community, or simply noise.

At the same time, nano contracting can reduce net capacity usage. Because Uber increases the revenue from driving, it can lead to greater road usage. Nonetheless, a study on Uber's effects with respect to road capacity found that Uber actually reduced congestion by increasing vehicle occupancy²⁹⁰. Further, surge pricing possibly reduces the capacity load in time of great demand.²⁹¹ A study of car sharing found improved welfare, especially among lower-income consumers. The authors propose that resource sharing can be "an economic force that democratizes access to a higher standard of living."²⁹²

What contracts can do, contracts can also undo. One lesson from copyright law is that there are strong upstream pressures to use contractual schemas to limit the ability to utilize property rights downstream.²⁹³ If aggressive nano leasing reduces demand for goods, if it increases bandwidth usage, or if it allows owners to extract rents from goods, producers may seek to use contractual mechanisms to prevent nano leases. As an analogy, producers of electronic devices have made it deliberately difficult to contract out repair services of one's devices outside of the producer.²⁹⁴ This limitation led to the formation

289. See *supra* note 240.

290. See Samuel Fraiberger & Arun Sundararajan, *Peer-to-Peer Rental Markets in the Sharing Economy* (N.Y.U. Stern School of Business Research Paper No. 19, 2017), https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2574337 [<https://perma.cc/A98U-JTYA>].

291. For a general review, see Volker Stocker, Aaron Kolleck, Saba Rebecca Brause & Nadine Schawe, *Navigating the Landscape of the Sharing and Gig Economy Literature: A Systematic and Interdisciplinary Review* 10 (Sept. 2021) (unpublished manuscript), https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3773458 [<https://perma.cc/6WQX-3TCG>].

292. Fraiberger & Sundararajan, *supra* note 290, at 22 (finding that peer-to-peer rental marketplaces "have a disproportionately positive effect on lower-income consumers").

293. See Guy A. Rub, *Copyright Survives: Rethinking the Copyright-Contract Conflict*, 103 VA. L. REV. 1141, 1157 n.69 (2017).

294. See Roy Shapira, *Consumerist Waste: Beyond Repair*, 122 MICH. L. REV. (forthcoming 2024) (reviewing AARON PERZANOWSKI, *THE RIGHT TO REPAIR: RECLAIMING THE THINGS WE OWN* (2022)).

of a large advocacy coalition demanding a right to repair.²⁹⁵ In a similar fashion, Internet providers may limit the ability to share bandwidth in its terms of service. Should there be a right to nano lease?

In sum, nano leasing offers a way to drastically increase the utilization of assets. This effect can usher in great social advances, contribute to the ethics of consumption, and reduce the resource load on the planet. These benefits notwithstanding, a move from property to contract raises several difficult concerns. There is the philosophical question about autonomy and self-definition in a world where little belongs to us. Then there are some distinctly legal questions about the classification of nano contracts and the type of rights that should be associated with a nano lease, relative to a macro lease. Distributionally, nano contracts have ambiguous effects, and there are at least some areas where few will be enriched at the expense of the many. The passage of ordinances in many cities against short-term rentals exposes how expanding rental rights can have significant effects on communities.²⁹⁶ As we move to a nano contract future, these questions will become increasingly important.

VI. NANO GIGS

A. Nano Work and the Problem of Casual Work

Nano jobs — like keeping a watchful eye on someone’s laptop for a minute or helping to replace a punctured tire — become possible with nano contracts. What would be the impact of nano contracts on labor markets? For a close comparison, the gig economy has had a profound impact on the lives of millions of Americans. Estimates are speculative, but one finds fifty-nine million adults participating in it — almost thirty-six percent of the entire U.S. workforce.²⁹⁷ This transition from jobs to gigs represents a shift towards the utilization of skills on a more casual basis than traditional employment contracts and independent contracts. However, the gig economy has not always been a positive force, and the impact it has had on employment and employee rights has been a major point of contention and focus of scholarly debate in recent years.²⁹⁸

295. *Who We Are*, RIGHT TO REPAIR, <https://repair.eu/about/> [<https://perma.cc/LN2N-AFW6>].

296. Amanda Hoover, *The End of Airbnb in New York*, WIRED (Sept. 5, 2023, 6:00 AM), <https://www.wired.com/story/airbnb-ban-new-york-city> [<https://perma.cc/9PF3-MBBA>].

297. Chris Kolmar, *23+ Essential Gig Economy Statistics [2023]: Definitions, Facts, and Trends on Gig Work*, ZIPPPIA (Feb. 16, 2023), <https://www.zippia.com/advice/gig-economy-statistics/> [<https://perma.cc/8H8S-UPZK>].

298. See Altanshagai Batmunkh, Maria Fekete-Farkas & Zoltan Lakner, *Bibliometric Analysis of Gig Economy* (May 7, 2022) (unpublished manuscript),

There is plenty of room at the bottom, even in labor markets. Indeed, services such as MTurk (wherein “a worker might be paid \$1 to watch a 1-minute video and write the first five words that come to mind”²⁹⁹) already blur the line between micro and nano contracts. Many people are willing to use their idle time, such as during commutes or in between meetings, to engage in short-term paid tasks. For example, individuals with relevant expertise could provide casual customer service, solve technical problems, label data for AI projects, monitor security cameras, clean public spaces, or recharge electric scooters. Just think of the users of public transportation and how they can leverage the long, circuitous rides if they could access nano jobs on their commute. The potential applications of nano contracts in labor markets are vast and could provide new opportunities for individuals to earn income and for businesses to access specialized skills on demand.

The rise of the gig economy has made the point straightforward. There is a large untapped market for labor, and tapping into it could vastly improve the fortunes of millions. Nano work offers workers the opportunity to engage in work with little commitment. There is also an important, less obvious progressive element to fleeting nano engagements. One lesson from policies like California Bottle Bill (whereby a small payment is paid when bottles are properly disposed)³⁰⁰ is that providing opportunities for people to work on a casual, non-committed basis can serve as an important anti-poverty tool.³⁰¹

B. The Legal Policy on Nano Work

Considering the regulatory implications of nano gigs requires a sense of their effect on the rights of workers. A good source of inspiration here is the gig economy, although in some ways “it is too early to say”³⁰² what the net effects are, to borrow from Zhou Enlai.

https://papers.ssrn.com/sol3/papers.cfm?abstract_id=4102964 [https://perma.cc/C46D-YCPM] (showing the dramatic growth of articles discussing the gig economy from 2014–2022).

299. Oranburg & Palagashvili, *supra* note 101, at S228.

300. CAL. PUB. RES. CODE § 14572 (2023).

301. Martin Medina, *The Informal Recycling Sector in Developing Countries*, GRIDLINES, Oct. 2008, at 1, 1 (“In developing countries about 1 percent of the urban population — at least 15 million people — survive by salvaging recyclables from waste . . .”). Note, however, that informal waste collection comes at a serious health risk. Eric Binion & Jutta Gutberlet, *The Effects of Handling Solid Waste on the Wellbeing of Informal and Organized Recyclers: A Review of the Literature*, 18 INT’L J. OCCUPATIONAL & ENV’T HEALTH 43, 44–48 (2012).

302. William P. Alford, *Exporting ‘The Pursuit of Happiness,’* 113 HARV. L. REV. 1677, 1705 (2000) (reviewing THOMAS CAROTHERS, *AIDING DEMOCRACY ABROAD: THE LEARNING CURVE* 1999) (recounting the Zhou Enlai saying).

One persistent line of critique against the gig economy depicts its value as mere regulatory arbitrage. That is, rather than providing any actual value, platforms like Uber and Airbnb who characterize themselves “as mere providers of a software app” in fact do so to “avoid many of the safety, hygiene, and other regulatory requirements that apply to taxis and hotels [S]haring economy firms flourish by reproducing existing services without the same societal restrictions.”³⁰³ Recent work has attempted to evaluate these concerns. Using an extensive data source, researchers from Harvard Business School and the London School of Economics concluded that this critique may be overstated.³⁰⁴ They found that regulatory arbitrage only explains part of the value of such labor agreements.³⁰⁵ In fact, they find that this economy provides tremendous value to workers who earn staggeringly twenty-six percent higher wages relative to their alternative opportunities.³⁰⁶

Another critique comes from the potential transformation of employment law to contracts. Employment law is meant to create a mandatory framework that constrains private contracts and offers some minimum protections for workers.³⁰⁷ The gig economy has been accused of creating a new class of workers,³⁰⁸ what economist Guy Standing calls the “precariat,”³⁰⁹ whose source of income is ever contingent. Many legal scholars, such as Catherine Fisk, have thus called for an expansion of labor protections to these workers.³¹⁰ A large legal battle is currently underway, attempting to define Uber drivers as employees of Uber.³¹¹ Recently, the Supreme Court of England ruled that Uber drivers are workers,³¹² although it left open questions of whether they are also employees.³¹³ On this side of the pond, Uber drivers are still not recognized as employees, although the legal battle contin-

303. Ryan Calo & Alex Rosenblat, *The Taking Economy: Uber, Information, and Power*, 117 COLUM. L. REV. 1623, 1626–27 (2017).

304. See Christopher T. Stanton & Catherine Thomas, *Who Benefits from Online Gig Economy Platforms?* 1 (Nat’l Bureau of Econ. Rsch., Working Paper No. 29477, 2021).

305. See *id.* at 2–7.

306. *Id.* at 2–3.

307. See *NLRB v. Jones & Laughlin Steel Corp.*, 301 U.S. 615, 622 (1937) (protecting the “rights of employees to self-organization and to select representatives of their own choosing . . . without [employer] restraint or coercion”).

308. See Stocker et al., *supra* note 291, at 3.

309. GUY STANDING, *THE PRECARIAT* vii (2014).

310. Catherine Fisk, *Hollywood Writers and the Gig Economy*, 2017 U. CHI. LEGAL F. 177, 177–78.

311. See, e.g., Kate Conger and Daisuke Wakabayashi, *Massachusetts Sues Uber and Lyft Over the Status of Drivers*, N.Y. TIMES (July 14, 2020), <https://www.nytimes.com/2020/07/14/technology/massachusetts-sues-uber-lyft.html> [<https://perma.cc/L62B-ZEBC>].

312. *Uber BV v. Aslam* [2021] UKSC 5 [93] (appeal taken from Eng.).

313. *Id.* at [126].

ues.³¹⁴ The difficulties imposed by Uber to legal classifications are an order of magnitude larger for nano contracts. If Uber drivers' involvement with the platform can be measured in hours, then nano work will be measured in minutes at most. This will make it ever more difficult to allot nano workers vacation days, social benefits, minimum wage, and other employment protections. The policy reaction can be to adapt labor regulation to the nano economy, but it may be that "little good has come from trying to force the square peg of how people work today into the round hole of 1930s-era labor law."³¹⁵ Instead, it might be necessary to expand the social net, either through Universal Basic Income or other social programs, regardless of employment status.³¹⁶

A different type of reaction comes from focusing on those who live the most precarious lives. Some forms of nano employment solve a longstanding problem among those who face barriers to joining the formal job market for reasons such as discrimination, criminal history, and mental wellness. One unexpected lesson from bottle recycling programs is that they provide an important source of income for extremely poor households; by one estimate, as much as 6.8 percent of their annual income.³¹⁷ Nano employment, like the bottle recycling example, can be an important anti-poverty mechanism.

Before concluding this Section, a brief remark on work and the self. Just as much as nano leases solve the problem of asset underutilization, nano contracts can be cast as solving the problem of labor underutilization. But is this a problem? To some, idleness and leisure are activities (or anti-activities) that help define the self. When one works, one is under the command and prerogative of the employer. If nano contracts expand the space of life designated as work, they shrink the space that is more easily identifiable as autonomous, where our own caprice reigns. Philosopher Byung-Chul Han has chastised late-stage capitalism as an era where exploitation comes from the self: "[E]veryone carries a work camp inside."³¹⁸ On this view, nano contracts threaten the last vestiges of individuality by expanding the fences of our work camp to every second of leisure.

314. See Michael C. Harper, *Using the Anglo-American Respondeat Superior Principle to Assign Responsibility for Worker Statutory Benefits and Protections*, 18 WASH. U. GLOB. STUD. L. REV. 161, 164–65 (2019) (describing how the rise of digital platform work without traditional employment contracts has led to "a halting and uncertain judicial response to the challenge of defining the employment relationship").

315. Oranburg & Palagashvili, *supra* note 101, at S232.

316. See Miranda Perry Fleischer & Daniel Hemel, *The Architecture of a Basic Income*, 87 U. CHI. L. REV. 625, 625–26 (2020).

317. Bevin Ashenmiller, *Economic Underpinnings of Recycling and Waste Disposal Policies, The Effect of Bottle Laws on Income: New Empirical Results*, 101 AM. ECON. REV. 60, 64 (2011).

318. BYUNG-CHUL HAN, *THE BURNOUT SOCIETY* 19 (Erik Bulter trans., 2015).

I hesitate to offer a general response to such general philosophical concerns. However, it is at least worth noting that for many people, shorter engagements can be life changing. The gig economy allowed many people who were shunned by traditional labor markets to find a source of income — single parents who could not commit to a regular nine-to-five job, small business owners who had seasonal lulls, or a recent graduate waiting to land her first job. Nano gigs can do the same for those looking to utilize extra time waiting on the bus or at the doctor's office.

In sum, this Section presented a potential application of nano contracts to employment. The flexibility they offer is unmatched and the potential is tremendous. But nano work also makes the legal challenges of defining employment, and ensuring employee rights, harder than ever. If employment collapses to contract, a century of worker rights advocacy will crumble. Nano work also raises some preliminary questions about inequality and the need for demarcation between the space of work and the space of self.

VII. NANO ACCIDENTS

Famously, the Coase theorem holds that the primary reason why we need tort law is transaction costs.³¹⁹ Accidents, like sparks emitted from passing trains into adjoining fields, create costs and risks. If transaction costs were low, these problems could have been solved by farmers and railways directly, as they would negotiate to the efficient outcome. But, as Coase and the legal scholarship that built on him vividly recognized, ours is not that world.³²⁰ In our world, transaction costs are sufficiently high to prevent such bargains, making it necessary for the law of tort to decide the outcome of accidents. Since then, some of the most important works in tort theory have tried to design rules that would approximate the results of bargains under ideal conditions.³²¹ As the sophistication and complexity of this literature shows, the task of designing optimal tort rules is challenging, and real-life tort rules likely fall short of this ideal.

Nano contracts will not abolish transaction costs, but they can make many of them close to trivial. The four-way stop illustrates a situation where transaction costs impede the efficient allocation of the scarce resource (i.e., right of way) as it will be unrealistic for drivers to discuss among themselves who should get the right of way.

319. See Ronald H. Coase, *The Problem of Social Cost*, 3 J.L. ECON. 1, 26–27 (1960).

320. See Richard A. Posner & William M. Landes, *The Positive Economic Theory of Tort Law*, 15 GA. L. REV. 851 (1981).

321. See Keith N. Hylton, *A Missing Markets Theory of Tort Law*, 90 NW. U. L. REV. 977, 978 (1996).

Traditionally, contracts and torts involve mostly separate realms. While contracts are based on agreement and intent, torts address non-consensual interactions — accidents. The contention here is that nano contracts expand the range of possible consensual agreements. As such, they can turn large spheres of tort law into contract law. To evaluate this contention, let us consider such an instance, using a modified version of the scenario suggested by Coase.³²²

A train is speeding down the tracks in Iowa. Suddenly, the train's computer reports an imminent electrical load. To avoid damaging the engine, the operator must quickly decide where to emit the sparks: to the right, where there is a corn field; or to the left, where there is a soybean field. The operator knows that the sparks will cause damage either way. A decision must be made — quickly. What should the train operator do?

Tort law tries to guide the operator's decision. Under the rules of tort law, the train company will have to pay the field owner for all the harm its sparks caused.³²³ The hope is that if the train company will internalize the costs of the accident, it will be motivated to minimize the amount of harm its sparks cause.³²⁴ However, applying tort law in this situation is problematic. Estimating the actual harm caused by the sparks is difficult, and it is likely that the legal system's assessments deviate significantly from the true amount of harm inflicted. This is further complicated because juries may be systematically biased in favor of farmers or trains, so damages will not equal the true harm, even on average. Another complication is the effect of time. Currently, the market price for soybeans is much lower than corn.³²⁵ But these prices fluctuate heavily over time and the operator must decide without a confident sense of what prices are or will be at the time of adjudication.

Now suppose the market rates for soybean and corn are \$1,118 and \$758 respectively — admittedly, this example requires more in the way of suspension of disbelief — and that the farmers have a nano contract app that can automatically communicate with adjacent conductors. Using a real-time lowest price auction, the conductor can negotiate the accident with the farmers. Neither farmer wants the sparks to cause harm to their crops, but the corn farmer knows that the ex-

322. Coase, *supra* note 319, at 29.

323. See generally Mark F. Grady, *Common Law Control of Strategic Behavior: Railroad Sparks and the Farmer*, 17 J. LEGAL STUD. 15, 19–25 (1988) (reviewing tort liability for emitted railroad sparks).

324. Richard A. Posner & William M. Landes, *The Positive Economic Theory of Tort Law*, 15 GEO. L. REV. 851, 854 (1980).

325. See *National Agriculture Statistics Service: Crop Values Annual Summary*, U.S. DEP'T OF AGRIC. (Nov. 13, 2023), <https://afdc.energy.gov/data/10338> [<https://perma.cc/83P4-XCSJ>].

pected harm to their field is \$1,118. Therefore, they bid \$5,000 to protect their profits. This allows the corn farmer to come out ahead in the event of an accident. The soybean farmer also sees an opportunity to protect their profits. Since the expected harm to their field is only \$754, they can outbid the corn farmer and ask for only \$4,000. Even at this reduced rate, the soybean farmer will come out ahead from the accident. Since they will still profit even if they bid \$3,000, they will underbid accordingly. Through this split-second auction process, it is expected that the soybean farmer will win with a bid of \$1,117. This will cause the conductor to emit sparks onto the soybean field, causing harm of \$754. The soybean farmer comes out \$363 ahead, and the more valuable crop is saved.

From a social perspective, this is the desirable outcome — we want the inevitable spark discharge to cause minimal harm. The tort system, however, cannot guarantee this outcome because its valuation only occurs after the critical decision has been made. On the other hand, a nano contract can assure that this desirable outcome will follow. It is worth noting that even if the train's computer could consult commodity prices in real-time, this outcome would not be guaranteed. Negotiated contracts offer a real advantage over market prices, especially when the owner plans to use their assets in nontraditional ways.

Nano contracts also offer a distributional advantage. Under the tort system, the soybean farmer is only entitled to \$754, whereas under the nano contract system, the farmer could recover \$1,117. If, in a given context, victims are systematically poorer than tortfeasors, or if tortfeasors can escape judgments, this would be a progressive improvement over the status quo.³²⁶ But even absent such distributional considerations, a working system of nano accidents is better suited to promote society's goals.

If accidents were completely subject to contracting, we might have to worry about a different problem. If an accident is inevitable, the farmers act as a monopoly, and they can demand an arbitrarily high price from the train company. Tort law, however, breaks this monopoly. If the parties fail to negotiate, the standard rules of tort law apply. This means that the train company will have to pay the farmer for the harm caused, as later assessed by the court. This assures us that the parties will nano contract only when they deem the outcomes superior to those of protracted litigation with uncertain valuation.

A broader question is the dynamic effects of nano contracts on accidents. If this stretch of train tracks is accident-prone (and there

326. See Richard A. Epstein, *The Social Consequences of Common Law Rules*, 95 HARV. L. REV. 1717, 1734–35 (1982) (arguing that there tends to be an asymmetry of wealth between injurers and victims in personal injury litigation). On judgment evasion, see Arbel, *supra* note 137, at 27 (describing the incentives to shield assets from legal collection).

are, indeed, various sites where accidents are common), the soybean farmer will soon make the same realization as Major Major's father in *Catch-22*.³²⁷ That is, she can make more money from not growing anything. That way, she can collect \$1,117 every time a train emits sparks with little effort.³²⁸ While this seems initially like a perverse outcome, it is actually quite desirable. The farmer would only abandon their crops if the probability of accidents is sufficiently high. But if accidents in an area are so common, society is well served by having safe areas where sparks can be discharged. On the other side of the ledger, train companies may invest more in antispark technology to avoid those regular and predictable payments.

This example offers a view on how nano contracts can efficiently minimize harm to victims from accidents and offer compensation for the residual harm that is agreeable to the victim. Such a solution can be extended to many other instances, although caution is required. For reasons that roughly track the discussion on the commodification of queues,³²⁹ we should be wary about the "contractualization" of accidents that involve bodily harm. In such cases, nano contracts can violate deep moral and social norms. But in many other cases, like those involving trespass or property damage, nano contracts present an opportunity to rethink the alienability of accidents.

To generalize, the nano contract instantiates Coase's theorem that parties would negotiate the most efficient outcome in the absence of transaction costs.³³⁰ If accidents cannot be economically prevented, the nano contract would ensure that the harm is minimized. In any event, the optimal result would ensue, but there will be no need for direct state involvement. The parties will negotiate the cost of accidents among themselves. Further, if society cares about the distribution of costs, it can do so via changes to the background tort regime.

VIII. CONCLUSION

At this late point, some readers will find themselves in one of two groups. One group will see nothing inevitable about nano contracts. A legal sci-fi that can be easily dismissed out of hand. Another group will have the exact opposite reaction: *nihil sub sole novum* (nothing new under the sun). To them, nano contracts amount to no more than a rebranding of gig economy agreements, if not of plain vanilla con-

327. JOSEPH HELLER, *CATCH-22* 81–102 (1st ed. 1961).

328. Under the tort system, however, the farmer will not be able to collect anything unless she grows crops. Thus, in accident-prone sites, tort law can lead to excessive and futile investment.

329. See *supra* Part IV.

330. See Coase, *supra* note 319, at 42.

tracts. The former will find nano contracts fantastic, as they will never materialize; the latter will find them trite, as they have always existed.

If there is still room for pleading with these readers, I think both groups have missed out on a key aspect of the Article. Consider the wise insight of science fiction author Frederick Pohl: “[A] good science-fiction story should be able to predict not the automobile but the traffic jam.”³³¹ Accordingly, the point here is not to make precise predictions to two decimal points about a bright future, or to claim to have reinvented the law of contracts. The goal of this Article is to think, in a sustained manner, about the culmination of deep existing trends, such as the digitization of transactions, “nanonization” in the XaaS sphere, minimization of transactional scale, and the tokenization of ownership.³³² *Transactions want to be small.* What emerges from this investigation considering the history of contracts is the insight that scale has a quality of its own. Smaller transaction scale opens new markets, some exciting and liberating, others troublesome and antithetical to our values. Diminishing transactional scale brings with it both the car and the traffic jam. Paying attention to these implications is worth the price of admission.

There is plenty of room at the bottom. While I am cautiously optimistic about the future of nano contracts, there is definitely room for good faith disagreement over whether the net is positive or negative. Clearing up lines effectively, liberating people from the onus and the chase of ownership, and providing new job opportunities can be socially transformative. At the same, we can recognize that there is certainly something unheimlich about a person without possessions (or rather, a person with unlimited possessions, but none of them hers) and something unsettling about contracting for accidents. Sandel’s romantic view of the “queue ethics” clearly shows that some find it uncanny to let those in a rush or with less patience buy priority from those willing to sell it, and letting people cut in line to the voting booth certainly triggers ethical goosebumps.³³³ These differing judgments suggest that there is also plenty of room for scholarly analysis: which future trajectory do we want to pursue? How might we influence the market? And on a more meta level, should we think about these issues now or let the market play out and attempt to repair the issues ex post?

This Article did not attempt to solve all these traffic jams. Rather, it seeks to offer a clear perspective on nano contracts, their structure, and legal implications for lines, property, employment, and torts.

331. Frederik Pohl, *The Great Inventions*, GALAXY MAG. SCI. FICTION, Dec. 1968, at 6.

332. See *supra* Part III.

333. SANDEL, *supra* note 200, at 28.

Hopefully, these are challenges that would urge us to think about new frameworks the next time we are stuck at a four-way stop.