Trickle Down Engineering

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Trickle-Down Engineering

Abstract

In much the same way that trickle-down economics posits that enriching those at the top will eventually benefit society as a whole, professional education policy—particularly in engineering—has long adopted a supply-side framework. This approach assumes that simply increasing the number and/or quality of trained professionals will inevitably lead to societal benefits, economic growth, and innovation. But just as critics of trickle-down economics highlight its failure to address structural inequality or ensure broad prosperity, the supply-side logic in education often overlooks issues of equity, distribution, and contextual need. Engineering education, for instance, tends to emphasize producing more or 'better' graduates rather than aligning graduates' capabilities with societal needs – the actual demands of underserved communities, evolving technological systems, workforce changes, and long-term sustainability. The results of this paradigm are potential oversupplies in some disciplines (e.g., mechanical engineering) and shortages in others (e.g., electrical and civil engineering). The emphasis on quality, broadly defined, has been a perennial theme in engineering but can marginalize engineering-adjacent pathways such as public interest technology or community-responsive design. Moreover, the trickle-down model incentivizes credentialism and prestige rather than societal alignment, replicating elite access and reinforcing stratified labor markets. As with trickle-down policies, the underlying assumption is that societal benefit will eventually "drip" from high-skill, high-wage professions outward. Yet this ignores the role of demand-side planning, institutional accountability, and structural incentives that shape where and how professionals actually contribute. Rethinking engineering education policy through this lens suggests a need to shift from simply growing supply to cultivating distributed opportunities for meaningful impact—especially for students whose aspirations are oriented toward service, justice, or systemic change.

Should we educate engineers?

Why should we educate engineers? Or perhaps a better way to ask this question is why should society invest in engineering education when there are other pressing policy goals? There are of course many possible answers to this question; this paper seeks to clarify the various rationales—here termed *dominant justificatory frames*—for public and private investment in engineering education specifically and higher education more broadly. While the reasons for education can become contested [1], the goal in this paper is not to provide a justification, but rather to explore what these frames are, how they have shifted over time, and the extent to which they draw from and support larger themes in society – particularly economic and political trends. The first part of this paper addresses the justificatory frames and how they have shifted over time. The second part explores justificatory frames more deeply by connecting them with economic models, leading to a discussion in the last part of the paper that the shifts in the framing of engineering education over time seem to have led to currently policies that can best be described by a construct that we term “trickle-down engineering”.

To understand the construct of trickle-down engineering it important to recognize the extent to which higher education is politicized, subject to economic policy, and how this affects individual choices about attending college. While context has always affected educational choice, recent events and the policy goals of the Trump administrations have increased both scrutiny of, and actions to change, the overall system of higher education and peer-reviewed research. Despite the political rhetoric, there is not much serious debate over the benefits of going to college. A recent report by the College Board [2] found that individuals with a college degree have higher income, employment prospects, retirement plans, voting rates, civic engagement, health outcomes, and shared activities with their families. The current debates about college are largely fueled by politics and questions about whether the benefits are worth the cost. The ‘sticker price’ of college has increased at a significantly faster rate than the consumer price index over the last five decades, leading to a growing public perception that higher education is not worth the cost. A 2025 Gallup poll found that 42% of U.S. adults expressed "a great deal" or "quite a lot" of confidence in higher education which was down from 57% in 2015 but up from a low of 36% in 2023 [3]. The reality of college cost increases is much more nuanced, however. Like medical care, college costs are difficult to control since the majority of budget expenditures (in the range 60% to 80% at most institutions) are for personnel. The fraction tends to be higher at private institutions than public, likely because private institutions spend slightly more of their budgets on instruction than do publics [4]. Cost increases are affected somewhat by increased administrative salaries, which have risen faster than faculty salaries over the last two decades, in what has broadly been termed ‘corporatization’ of higher education [5]. Costs have also been affected by significant shifts in state funding for higher education over time [6]; these shifts vary widely by state.

The public debates on the value of a college education are usually based on comprehensive fees—i.e. the ‘sticker price’ of college—rather than the actual cost, which is modified by the discount rate (the percentage of advertised tuition a student pays). Discount rates have increased significantly—from 40% to 56% for privates and 10% to 20% for publics—over the last 25 years, again with high variation between institutions; discount rate is generally inversely proportional to prestige [7]. Currently about 60% of students receive financial aid. Due to partially to the increase in financial aid, the most recent reports of college pricing [8] show the public perception of college’s high cost is not completely accurate. When the discount rate is taken into account and adjusting for inflation the net cost of private college attendance in 2025 dollars stayed relatively flat from $37,580 in 2006-07 to an estimated $37,380 in 2025-26. The shift in public four-year institutions was from $20,970 to $21,340. The inflation-adjusted change in costs was driven in part by increases in the Consumer Price Index. It is important to note, however, that increasing financial aid significantly impacts university budgets, requiring cutbacks or even austerity in other areas. While this discussion is somewhat wonkish, the public debate over the value of a college degree influences universities justifications for their existence, budgets, and tax-free status which recent political events show is not guaranteed.

In brief, while college education is correlated with better life, civic, and economic outcomes the increasing cost of a college degree (which has been difficult to control), falling public perception of its utility, and increasing politicization of education have put new political and perceptual stresses on the higher education system. Engineering degree programs have, to date, been able to dodge many of these pressures because they are seen as having a good return on investment – both for individuals and for society as a whole. The return to individuals stems from calculations of the return on investment (RoI) of a college degree which is used to compare investing in a college degree vs. other possible investment such as stocks, certificates of deposit, or real estate. Engineering degree holders typically start out with higher salaries than other graduates, but have lower wage growth over time due to the high starting salaries [9]; going into management increases wage growth. Engineers do have the overall highest lifetime earnings of all STEM disciplines, which leads to high RoI despite longer times to complete degrees and additional fees that raise the cost of obtaining a degree. Note as with all highly aggregated data there are significant within-sample differences. On average, engineers pay off student debt within five to eight years of graduation, while the average break-even point for all undergraduates is the former student's mid-30s [2]. There is some evidence that part of the high RoI comes from the 'non-routineness' of engineering work [10], the ability to move into management, and high graduate degree attainment, although this varies greatly by race [11].

Dominant justificatory frameworks

The value of an engineering degree to an individual and the value to society are not directly comparable. Thus, the engineering disciplines within higher education seeks to portray themselves positively for policy makers by highlighting the societal benefits of an engineering education – these reasons are the *justificatory frameworks* discussed previously. The most cited reasons are those of economic competitiveness: engineering is viewed as driving innovation-based economic growth and higher GDP output per worker; the role the engineering workforce plays in supporting advanced manufacturing, infrastructure, and technology exports; and the 1.8× – 2.3× wage multiplier effect, i.e. that every engineering job creates up to two additional support jobs [12], [13], [14]. Since at the end of the day every elected official needs to answer the question of how they created jobs in their district, supporting engineering is like the old adage that nobody got fired by buying IBM [15]. Another justification is that technological competitiveness impacts upon both economic and national security. Heywood recently released an in-depth, multi-decadal analysis of how the UK has shaped policies for technological excellence [16]. In the US, policy makers (c.f. [17], [18]) have historically viewed engineering talent as essential for defense technology superiority, cybersecurity, energy independence, and the resilience of critical infrastructure. Talent creation is supported through programs such as the National Defense Education Program (NDEP) [19]. Policies often derive from events, such as semiconductor supply chain disruptions during COVID giving rise to the CHIPS act. A third rationale for support of engineering degrees is that because of their high individual RoI and job placement rates, they serve as exemplar programs for higher education policy goals. In other words, engineering programs serve as proof that higher education can serve as a gateway to stable, high-wage employment; benchmarks for effective workforce pipelines due to high placement rates into jobs post-college; and, in past administrations, a way to close racial and gender income gaps by expanding STEM access.   Fourthly, engineering degrees and the maintenance of a workforce 'pipeline' [20], [21], [22], [23] support other policy goals. These include (depending on the administration) those directly related to engineering such as modernizing transportation, energy grids, and water systems and achieving climate goals. Economic policy goals—beyond a narrow focus on technology or infrastructure—also serve as a rationale, with engineering viewed as an enabler of innovation ecosystems, supporting patent production, R&D productivity, regional innovation hubs, and university–industry collaboration with engineering degree programs are seen as "multipliers of innovation capacity" [9], [24], [25], [26]. Finally, there is engineering's internal justifications as being supportive of human welfare by contributing to civic and humanitarian goals such public safety, clean water, housing, and health technologies. Engineering's own messaging [27], [28] and adoption of professional ethics [29], [30], [31], [32] emphasizes engineering as service to humanity to enhance its appeal for younger generations. It should be noted, however, that broad ranging policy issues are 'convergent problems' [33] which require participation of engineering as a co-equal partner with other disciplines rather than being 'owned' by engineering.

These justificatory frameworks for engineering education are societally embedded and political despite engineering's well known apolitical stance [34], [35], [36]. These justificatory frameworks also deeply incorporate economic and financial logic such as market efficiency and competition, so the frameworks change with time as society shifts. For example, there has been a decades long shift away from the Keynesian liberal polices of the 1930's to 1960's that saw business as stakeholder-drive and supporting social welfare and employment. This shift encompassed moving from a manufacturing-based to a service and knowledge economy, and then the early stages of neoliberalism in the 1970's [37], [38], to the Reagan revolution of the 1980's, and finally the 2008 financial meltdown and increasing criticism of capital-centric policies [39], [40], [41], [42] in vogue today. In brief, the decades leading to this point in time have seen economic and political shifts from stakeholders to shareholders.   However, much of the identity we currently claim for engineers was developed during the period of Keynesian liberalism when engineering was seen as a rational and strategic profession engaged in national development, state-led economic planning, infrastructure, and defense with corresponding high social status [43], [44], [45]. Engineers' role in planning, centralization of resources, a holder of public trust, and technological advancement all contributed to engineering's identity, but also the current issues of exclusion and racialized norms [46].

The secondary impact of economic models on engineering education

Up to this point this paper has used a broad brush to highlight how economic and financial frameworks impact upon how both higher education and engineering education are valued, justified, and shaped. The more common justificatory frames for (engineering) education were outlined as well as how the economic and societal frameworks which inform them have shifted over time. In the remainder of the paper we go into more depth to explore the impact of supply-side and demand-side economic policies on engineering education.

As documented above, the post WWII era helped construct the engineering profession's espoused identity. During this time Keynesian policies focused on the demand side of the economy using public spending through economic stimulus and welfare programs when needed to boost consumer demand, drive economic growth, and maintain high employment. To review briefly, demand-side, Keynesian policies assert aggregate demand drives economic growth and employment, particularly during downturns. Thus, active government intervention acts as a counter-cyclical force, actively managing economic cycles through fiscal stimulus to boost demand and support pro-worker policies to reduce unemployment, stabilize income, and boost consumer confidence. Public investment in infrastructure engaged engineering directly, as did investing in education to promote social mobility. Under demand-side economic policies both engineering and education serve as public goods that benefit society and were therefore seen as worth investing in. The limits to demand-side economics showed up with the energy crises in the 1970s, a view that unions and governments were inefficient, and stagflation (rising inflation and unemployment). These were triggered in part from shifting away from a manufacturing economy, where Keynesian models worked well, to a service economy. Intellectual attacks from economists such as Friedman and Hayek and support from conservative organizations using documents such as the Powell memo [38] argued that tax cuts could provide economic stimulus; these arguments shifted from the managed economy to a more free market mentality and the rise of shareholder capitalism which called for more mobility of capital.

The "Reagan Revolution" formalized the policy shift to a supply-side, also known as "trickle-down", economic model. Under this paradigm policies focused on encouraging production, investment, and innovation with minimal state interference and less stringent regulation. The idea of an all-knowing 'free market' came to prominence; the free market was claimed to provide better guidance for the economy than the expert-focused interventionism of demand-side models. Thus, it was important to free up capital so it could be more mobile by cutting taxes and keeping inflation and interest rates low through monetary discipline, including austerity measures. Technological innovation became central to using the newly freed capital wisely, which helped shift the identity of engineering to be more innovative and entrepreneurial with increasing emphasis on the private rather and less on the public sector. In higher education the shift was to move away from education as a public good to a private investment that allowed the individual to become more competitive in the market [47]. Policy-wise, the shift to supply-side models resulted in the expansion of student loans, emphasis on college rankings, tying funding to educational performance (e.g. No Child Left Behind), the focus on STEM degrees, and education being viewed as an economic rather than social development strategy. Or as Berman [47] frames it, "By the 1980s, policymakers had begun treating education less as a right or a public good, and more as a tool for improving productivity and competitiveness."

These long-term shifts changed justificatory frameworks for engineering education by changing the language those in higher and engineering education use to frame their own work – these changes occurred over decade time scales, making them less visible. Students are increasingly seen as consumers, a framing that has been intensified by competition for enrollment both due to the coming 'demographic cliff' [48] and the fact that college budgets have become more precarious as discount rates have risen and state funding has dropped. Similarly, while there is strong pushback from within academia, education is increasingly seen by the public and policy makers as a service that produces degrees as a product, thereby reifying that education is a private rather than public good.

As engineering education adopts multiple justificatory frameworks, similarly economics has competing explanations as to the value of a college degree which impact upon engineering and education frameworks. The most common of these is human capital theory [49] which views education as an investment in skills that improve a person's productivity and earnings. Individuals thus seek to acquire education to gain marketable knowledge and competencies, which employers value. By being in demand, individuals have higher lifetime earnings; there is, in fact, a strong positive correlation between education and income. Policies that support expansion of higher education, an example is Pell grants, emerged from the human capital framework. In contrast, signaling theory [50]—and the related screening theory [51]—do not assume actual value-add from higher education. Rather degrees serve as signals of persons' pre-existing abilities and the reason individuals pursue education is to differentiate themselves in the job market through credentials. Screening theory is similar but hypothesizes it is employers rather than individuals who value degrees as a proxy for, or signal of, individual ability. These frameworks are often invoked in discussions of grade inflation since an over-abundance of credentials reduces the signaling effect and therefore the value of degrees [52]. By reducing the overall value of college degrees, grade inflation encourages students to apply to more prestigious schools or seek advanced degrees, thereby creating what has been termed an "educational arms race". Policies like more transparent, employer-focused credentials or micro-credentials also emerge from this framework. A third framework known as credentialism arose from the social sciences and emphasizes the symbolic power of degrees, seeing them as ways to preserve social hierarchies rather than as providing valuable skills to an individual [52], [53]. Policies focused on vocational education or skills-based hiring that help deconstruct social hierarchies are recommended in this framework.

While not as prevalent in defining education policies, there are lesser-known frameworks that impact on engineering education particularly given the recent concerns about AI. One of these is Skills-Biased Technological Change (SBTC) which posits that technological progress increases the demand for high-skilled labor that has cognitive, analytical, and problem-solving skills, while simultaneously reducing demand for low-skilled or routine jobs [54], [55]. As technology—the product of engineers' work—replaces more routine tasks, this leads to wage polarization where high-skill workers earn more, middle-skill jobs vanish, and low-skill jobs grow more slowly. This framework has been used to explain observed changes in the US workforce [56]. Under SBTC engineering education justifies itself through the ability to create innovative individuals capable of non-routine tasks. Interestingly, these include social as well as technical skills [57], providing a justification for the recurring debates on the value of transferable or durable skills like communication and teamwork in engineering curricula due to their higher market return. Examples in engineering education are project-based learning, an increased emphasis on collaboration, creativity, adaptability as well as employer calls for communication and teamwork skills. It was these calls that led to ABET's EC-2000 changes. More broadly SBTC is used to justify upskilling or retraining programs, however these have mixed results and are most effective when there is deep involvement from employers [58]. Otherwise they result in more contingent labor or gig work [59].

A framework that seeks to step outside the purely economic sphere is Sen and Nussbaum's capability approach [60], [61], which the authors are utilizing as a part of an NSF Revolutionizing Engineering Departments (RED) project. Sen sought to shift away from GDP and other economic measures of development based on the realization that the most significant issues affecting individual arise around distribution, rather than abundance, of resources. The capability approach seeks to maximize individuals' ability to live lives they have reason to value rather than simply maximize their income through their ability to compete in the labor market. Central to the capability approach are both capabilities—the actual opportunities people have to create lives they have reason to value—and functionings, which are how they express their agency in utilizing the capabilities to achieve valued ways of doing and being [62]. The capability approach is not well known in the United States, but is gaining adherents in the developing world. This paper will revisit the capabilities approach in the next section in a discussion of adaptive preferences.

The above review of justificatory frameworks from both engineering and economics shows that economic policies and frameworks impact upon the space of higher education policy, strongly influencing directions and trends in engineering education and the lived experience of students. As authors like Seely and Akera [63] have pointed out, engineering education has always sought to justify itself, for example in the post second world war era by reframing engineering as a scientific discipline, echoing the debates in the British Isles of the 19th century [16]. Similarly professional societies and accrediting bodies such as ABET provide institutional legitimacy through processes of standardization and external review based on putatively objective metrics [64]. While engineering education often creates its own internal justifications for its actions, preferences, and policies the discussion above shows that these justifications mirror larger societal and economic trends. Hence the claim of this paper that the majority of engineering degree programs operate on a mostly unconscious model of "trickle-down engineering".

Trickle-Down Engineering

This paper introduces the construct of "trickle-down engineering" (TDE) to succinctly capture the dominant economic narrative through which engineering education justifies its usefulness to society. TDE as a construct is intended to highlight how engineering education incorporates and replicates economic paradigms so that engineering educators and the programs and departments to which they belong can better identify and name the external forces they are subject to. The discussions that emerge from such identification, it is hoped, will enable engineering departments and programs to interrogate their own actions and surface unconscious assumptions. It is also worth realizing that despite being tied to external factors engineering should not be excessively bound by them. To aid in such activities a working definition of the construct of trickle-down engineering is:

> *Trickle-down engineering describes how engineering education programs justify their value primarily through their ability to produce elite-certified human capital for high-return sectors—such as technology, defense, and finance—under the assumption that institutional and societal benefits (e.g., funding, prestige, innovation) will "trickle down" by aligning their internal processes to top-tier industry demand. It foregrounds a supply-side logic, wherein educational success is measured by graduates' placement into high-status positions, and institutional success is reinforced through performance metrics, industry partnerships, and resource flows.*

This definition echoes, in some ways, the critiques inherent to credentialism but is refined more specifically for engineering education. Given that the US shifted to a predominate supply-side economic model four or five decades ago, there has been sufficient time to understand the larger societal effects of supply-side economics and draw rough analogies for how trickle-down policies might be evidenced in engineering programs. The ways that trickle-down engineering is enacted in degree programs include: 1) engineering programs justify themselves via the economic return of their graduates; 2) engineering departments compete to "supply" top-tier talent, leveraging relationships with industry for funding and rankings; 3) degree programs advertise high-salary job outcomes and elite placement as they compete in the market for students; 4) elite placement generates institutional prestige that trickles down, reinforcing social and ranking hierarchies; 5) supply-side logic sidelines the civic-focused education and public works in the post WWII era, undermining some of engineerings' own logic for its existence; 6) engineering degrees function both as status-marking tools and skill indicators; and 7) universities invest in engineering for rankings, grants, employer pipelines and to justify their economic impacts.

There are several prior studies that support the assertions of the trickle-down engineering framework. Tholen [65] researched how those within a putatively technical and skills-based occupation (software engineering) co-create the meaning of educational credentials. In software engineering while college degrees are not strictly necessary for employment due to the rapid rise of micro-credentials and alternative educational pathways, they are advantageous for elite career paths since they act as "credibility filters" which serve as symbolic currency. The social skills gained during elite education also open up career advancement tracks and more rapid promotion since they signal cultural fit. In this case the trickle-down effect evidences as a cultural signaling mechanism that impacts employer behavior, creates career stratification, and Weber's social closure. Similarly Wheelahan and Moodie [66] found that professional programs such as engineering use qualifications for occupational closure, utilizing governance processes through accreditation to make it difficult to practice without formal credentials. Professional disciplines assert specialist knowledge and neutrality—thereby excluding lay perspectives and civic accountability—which reinforces technical rigor [67] and elite placement, effectively sidelining civic-focused or student-centered missions. While engineering is often seen as a path to upwards mobility the degree of mobility is, as Tholen found, dependent to some degree on institutional status.

Trickle-down engineering implies that universities invest in professional programs like engineering and medicine despite the high cost since these programs secure external funding, improve rankings, and enhance reputational capital. Looking more broadly at higher education, research on the increasing alignment of higher education with a free market mentality indicates that educational credentials are becoming a form of capital in the labor market [68]. Education as capital creates a positive feedback loop that drives universities to increasingly operate as credentialing enterprises where education is judged by its economic returns and prestige signals rather than by the intrinsic societal value or civic contributions that underlay demand-side economic paradigms. This emphasis on prestige aligns with the construct of trickle-down engineering that programs justify themselves through their ability to produce highly placeable graduates in elite sectors under the assumption that benefits will accrue to the institution and society from this alignment. In brief, as Piketty found historical evidence that financial capital accumulates until catastrophic events redistribute or destroy it [42], trickle-down engineering predicts the same institutional hoarding for human capital.

To better understand how trickle-down engineering is expressed to students, the author looked at how universities market themselves to their external stakeholders. Three sources of advertisements were reviewed: the web sites of top 25 engineering school web sites (drawn from *US News and World Report* PhD-granting rankings from 2025), a random sampling (N = 74) of advertisements in ASEE's First Bell for a three year period, and on-line advertisements using Meta's Ad Library [69]. To perform the analysis of on-line advertisements searches were conducted using various combination of the terms *STEM*, *engineering*, *department*, *program*, *student*, *degree*, *college*, and *university*. Results were filtered to only analyze advertisements from ABET accredited degree programs [70] in the United States. For First Bell advertisements postings from the last three years were randomly selected from the author's email and tag lines extracted. A search of top 25 engineering school web sites obtained taglines of how they branded themselves. While a more comprehensive search is possible, the results returned are sufficient to illustrate how programs market themselves. Table 1 highlights taglines from some of the advertisements, where program or personal identifying information has been replaced with "###".

Of the taglines analyzed from Meta ads and public-facing websites, about 55% aligned with the values inherent to trickle-down engineering, about 35% were partially aligned, and 10% poorly aligned. The taglines from First Bell advertisements differed, with about 1/3 aligned, 1/3 partially aligned, and 1/3 misaligned. Analyzing themes of the advertisement and website taglines it was found most related to trickle-down engineering in some form. The most common was advertisements highlighting that education is a pipeline to high-paying industry jobs reflecting the importance of RoI and economic utility of a degree through which the individual will be rewarded for supporting market productivity. A second way these taglines support TDE is the close connection between universities and industry is reinforced in advertisements to demonstrate to students they can gain access to elite firms. Here universities demonstrate their close connections to industry, the more recognizable the better. Prestige is also commonly highlighted in advertisements, likely speaking not just to students and parents but also peer institutions.

Table 1: Selected taglines of university engineering program advertisements

Taglines	Alignment
95% of our engineering students are employed or in graduate school within 6 months of graduation.	Aligned
Our students work on sponsored research from companies like Boeing, Amazon, and Intel.	Aligned
Our engineering graduates earn a median starting salary of $82,000, one of the highest among all disciplines.	Aligned
Ranked in the top 10 for public engineering schools, ### Engineering leads in innovation and impact.	Aligned
### is your pathway to leadership in one of today's fastest-growing industries.	Aligned
This advanced degree equips you with high-demand skills.	Aligned
Solve the hardest challenge at work and learn from the best in the field.	Aligned
Earn your computer science degree online and gain skills for today's tech landscape.	Aligned
Advance your career on your schedule with our flexible MS in Mechanical Engineering.	Aligned
As a Top 25 Best STEM College, we offer more than just a degree—we help your student pursue big ideas.	Aligned
Advance your career in fields such as cyber security, engineering, or nursing	Aligned
Ready to change the world? ### offers high-profile research and valuable internships in a technological hot spot.	Aligned
Gain the knowledge and skills required for a successful career in the mobility industry.	Aligned
Here are 7 reasons why ###'s Engineering is an exceptional place to learn, build, research, and launch your career.	Aligned
Graduate with experience not just a degree.	Partial
Build skills for tomorrow exploring what excites you today.	Partial
Innovate with solutions that make an impact.	Partial
Become a leader in biotechnology.	Partial
Lead the future of engineering at the nanoscale.	Partial
Combine engineering and business in ###	Partial
### equips engineering students with the technical and ethical skills needed to tackle the challenges of tomorrow.	Partial
Culture. Research. Innovation. It's what makes ### different.	Partial
### teaches skills you can use in industries from manufacturing to medicine.	Partial
A degree that fits your goals not the other way around.	Poorly
Good Great programming skills.	Poorly
Explore your calling and broaden your horizons with a degree from ###.	Poorly

Prestige signaling ads were much more common in First Bell—about 1/3 of those analyzed—likely since First Bell is aimed internally to the engineering education community. Similarly, very few First Bell ads focused on students. In these advertisements prestige-based messaging trickles down from elite institutions, setting the standards for how all programs define success and thereby reinforcing status hierarchies and the notion of scarcity. The advertisements also seek to appeal to students who are seeking engineering degree programs that offer a streamlined, modular process to gain marketable skills; we hypothesize this is related to the increasing cost of college. Finally, there is a strong message of innovation, but its use seems to be mainly performative. Innovation is framed as a self-evident good, but for whom or to what end is left open. The third of First Bell advertisements that were misaligned with TDE often focused on societal good, highlighting the broader social utility of engineering through specific programs or research or the university's access-expanding efforts.

While some of the taglines do emphasize that college can be an environment for personal transformation or to learn civic responsibility, these are in the minority. While an analysis of how Carnegie classifications affected ad content was not conducted, the differing mission of institutions might help explain some of the variation. Civic goals such as regional engagement or equity in access from the demand side (discussed further below) were most common in these advertisements that are considerably less represented. While a more in-depth study of how engineering programs seek to market themselves is needed, the limited view of this study is supportive of the claim that many schools publicly align with the definition of trickle-down engineering. The shared institutional logic that shows up across a majority of engineering schools that emphasizes supply-side justifications (economic output, industry alignment) are deeply embedded in the program.

Revisiting the captivity of engineering

Steven Goldman [71] has claimed engineering is captive to society. This paper introduces the term "trickle-down engineering" (TDE) to express how engineering is also captive to economics. TDE seeks to capture how over time the espoused values of engineering—which have their roots in demand-side, technocratic governance systems—have shifted more to supply-side logics and away from civic and public works supported under previous economic models. At the level of students and parents, the impact of supply-side economics is most visible in the increasing volume of debates over the rising cost of college. As the Keynesian policies of the mid-20th century struggled with stagflation, economic models shifted from demand-side to supply-side, causing higher education to be increasingly viewed as a private good rather than a public benefit. The result for many colleges has been shifting to more austere budget models in order to provide a higher discount rate. At this moment in time, fears of demographic cliff are driving fiercer competition for students. As the real and perceived costs of college rise—and the reality here is subtle and unevenly distributed—there has been increasing focus on the return on investment (RoI) of college, which has been parsed out by major. In the justificatory framing of RoI education engineering appears to do well, with the highest RoI among engineering majors in most studies. There are, however several inherent tensions that make the picture more complicated. Because engineering is often seen as a gateway to the middle class [72] engineering students, although they do well post-college, often need more financial aid during college [73]. Engineering enrolls more Pell grant recipients [74], often has longer degree completions times, and as a result financial stress can be a major factor in retention of some groups of students [75]. In short, because education has become more of a private good, the costs have been increasingly borne by individuals who seek a higher return on their investment. Financial aid along with labs and higher faculty salaries make engineering programs the most expensive to offer – about 55% more than the median degree program cost [76]. As financial stressors increasingly have colleges look at net tuition revenue, they have begun to rethink engineering programs. While the future is uncertain, there is the potential in a time of increasing financial austerity for a reduction in the number of engineering programs; scarcity would enhance reputation and further drive TDE.

As economic language and values increasingly permeate society, including engineering education, degree programs have adopted this language into their justificatory frameworks. As discussed previously, there are multiple justificatory frameworks for engineering education. These are not mutually exclusive – a program can adopt multiple frameworks and even craft its curricular offerings around different rationales, even creating specialized programs like carve outs in business; an example is the EPICS program at Purdue University [77]. As discussed previously, the justificatory frameworks used by engineering programs build both on the values inherent to demand-side and supply-side economic models. These frameworks are contested since both demand- and supply-side theories make claims to support public welfare, for example that engineering drives innovation-based economic growth. A framework can cross both demand- and supply-side models such as engineering's role in supporting technological competitiveness that impacts upon both economic and national security. Frameworks reify the espoused values of engineers – to build public infrastructure for human welfare, but claims of public good can be co-opted—for example by organizations such as KEEN [78]—to highlight how engineering supports the common good through innovation, entrepreneurship, and technology-fueled economic growth. Underlying the other frameworks are moral-ethical frameworks focusing both on professional ethics [29], [31] and, as a subset, social justice [34], [79], [80], [81]. Each of these frameworks is used in different ways to enhance engineering's appeal to younger generations.

The term trickle-down engineering is intended to stimulate dialog about how most engineering programs are increasingly operating in a supply-side modality despite the espoused identity of public service drawn from demand-side models of the post WWII era when engineering had more prestige. Engineering education's self-narrative at first glance does seem better aligned with a demand-side model: we are public servants operating in larger social, governmental, and private industry systems to produce well qualified engineers who in secure and lucrative careers will build technology and system that broadly benefit humanity. In a song that is a reflective breakup letter with Elon Musk, the singer-songwriter Penelope Scott [82] recently captured the zeitgeist of engineering's message that you can do well by doing good:

> *I come from scientists and atheists and white men who kill God.*
> *They make technology, high quality, complex physiological;*
> *Experiments and sacrilege in the name of public good.*
> *They taught me everything, just like a daddy should.*
> *And you were beautiful and vulnerable and power and success.*

God damn, I fell for you, your flamethrowers, your tunnels and your tech.
I studied code because I wanted to do something great like you,
And the real tragedy is half of it was true.

There is, in fact, nothing inherently contradictory about being able to benefit humanity through technological innovation and making a good living. However, the construct of trickle-down engineering highlights that the supply-side model increasingly adopted by engineering programs is not free of ethical and moral consequences, and these can be misaligned with engineering's often-espoused identity. Adopting supply-side justificatory frameworks can sideline broader civic, equity, or locally responsive missions in favor of technical excellence and competitive signaling – this is what is observed in the analysis of advertising taglines for engineering degree programs. Identity, of course, is mutable and can change [83]. KEEN, for example, acts as a change agent that initially through funding grants, and more recently through faculty development, seeks to reshape engineering education to be more entrepreneurial. Similar, if blunter, federal policy changes have also sought to reshape the priorities of engineering education under the current administration. Given the financial stress many universities are under, there is considerable incentive to maintain or increase financial resources through partnership and/or compliance.

There are, however, potential perils in continuing on the supply-side path. In what follows it is important to distinguish there may be differences between what is good for the loosely-coupled system of engineering education as a whole [84] and what may be good for individuals or individual institutions. One potential peril over the long term is increasing credential asymmetry – engineering programs produce tiers of graduates that are putatively equivalent, but only the elite tier of institutions generates prestige returns for the program or promised individual financial returns for the graduates. Such differential prestige occurs in spite of organizations like ABET who seek to create a level playing field through accreditation. Another peril relates to the demand for engineering graduates. While it is generally believed that there is strong demand for engineers, in fact the US education system produces qualified graduates in excess of actual labor market demand [85]. What are perceived as shortages are often not due to a lack of qualified candidates but rather hiring difficulties stemming from specific industry expectations. Heywood [86] echoes this argument, stating the labor market is affected by preferences for entry-level workers with "up-to-date" skills and lower salary requirements over middle-aged engineers, leading to significant unemployment among older professionals. Another peril is the effect of offshoring creating a situation where technological innovation no longer guarantees an increase in domestic employment. So-called jobless innovation occurs when new technologies require fewer workers or when routinized work is off-shored to countries where qualified manpower is cheaper. It is likely that AI will significantly accelerate these trends [54], [87]. Finally, there is a growing demand for technicians and "middle-level" workers who have more than a high school education but less than a four-year degree. The Georgetown Center for Education and the Workforce also has found that the perception of shortages comes from increasing demand for quantitative and technological skills in the non-STEM workforce which draws graduates from the engineering workforce [9].

Credential asymmetry serves, as outlined previously, to support a systemic 'rich get richer' system archetype [88]. In this loop the ability of elite institutions to place graduates in prestigious industries raises institutional rankings, drawing more applications and potentially more full-pay students who benefit the university financially, generating more funding and opportunities for students that make them competitive for prestigious jobs. As discussed previously, it is not as much technical skill development as the transferable, durable, and social skills such programs impart along with access to career networks that make them attractive. These reinforcing loops are essentially credentialism – the possession of a degree matters less than where it's from and how well it aligns with elite expectations.

Another peril is that the pendulum that swung from Keynesian demand-side models to supply side models around 1980 may swing back, or unlike simple harmonic motion be more like a chaotic strange attractor, moving in a different direction altogether. Classic Keynesian models became less effective as the economy shifted from manufacturing to knowledge and services, and they could not effectively respond to stagflation in the 1970s. Yet as economic inequalities have increased, there is increasing public recognition of the negative effects of supply-side economics. For example, the US Gini index (a measure of how equitably economic resources are distributed) was about 0.38 in the late '60s compared to 0.49 today [89]; a shift of 0.1 can be sociologically transformative with income inequality having measurable impacts across economic, political, and social systems. The inequitable distribution of wealth and other resources are increasingly felt by younger generations facing wage stagnation and rising housing and education costs – exactly those we seek to recruit to engineering programs. Income inequality impacts on education through credential inflation where the wealthy can "buy" better outcomes through tutoring, legacy admissions, full-price (non-discounted) early decision admission, and unpaid elite internships. A recent example is the varsity blues scandal [90]. There are a range of predictions on the economic impact of generative AI [54], [87], [91] but if the shifts larger and faster in scale and rapidity as the transition to a service- and knowledge-economy then universities, which change slowly, may find themselves unprepared.

Finally, trickle-down engineering sidelines broader civic, equity, or locally responsive educational missions in favor of technical excellence and competitive signaling. The goal of this paper in defining trickle-down engineering as a construct is to help engineering educators visualize how these rationales—which are often espoused in engineering departments—have become secondary. An idea from the framework of the capability approach—adaptive preferences [92], [93]—provides insight. Adaptive preferences occur when a person unconsciously changes what they want or value because their real-world options are limited, similar to Aesop's fable of the sour grapes. Essentially, it is a psychological defense mechanism where people learn not to want what they cannot have, often as a way to reduce the mental tension of being in a difficult or unfair situation. In this case, students may be enticed in to engineering programs through their espoused human welfare and public service values drawn from historical demand-side narratives of engineering, only to find that the programs operate more on a supply-side mentality to place students in jobs the student has no real desire to fill. In this case adaptive preferences act as constraints on self-development. While higher education has a valid role in social conditioning and providing opportunities students could not envision prior to college, when the needs of the institution for prestige or placement overly constrain student choice this becomes an ethical issue. The fact that the capability approach seeks to theorize such issues and focus on creating opportunities for students rather than outcomes for employers may make it a viable model for institutions to reframe programs when the pendulum does swing away from supply-side models [81], [94].

In conclusion, this paper has introduced the construct of trickle-down engineering to help frame discussions around the espoused values of engineering degree programs and what values they enact. Trickle-down engineering is not necessarily a choice made by degree programs, but rather an organizational/institutional response to large-scale systemic changes. This paper has sought to clarify the system view by looking across scales and disciplines. The pressures on us (engineering faculty who are actors in a local system) are different from those on the institution which employs us, who is itself an actor in a larger distributed and loosely-coupled system. Faculty actions at most institutions are dictated by what is colloquially known as the 'iron triangle' of research-teaching-service which specifies the actions for which we gain recognition from our institution. A similar triangle of prestige-finance-mission exists for institutions. In this case it might be called a 'glass triangle' since it is both fragile and difficult to see. Neoliberalism and the supply-side economic models that higher education has increasingly come to rely on mostly recognize prestige and finance since these determine 'what is good' under free market ideologies. Neoliberalism seeks to define institutional mission around these poles. Mission, however, defines the moral purpose of the institution; the rationale by it justifies its (tax free) existence in society. Although often just given lip service, institutional missions provide moral criteria by which universities should be judged. As Sedlacek has eloquently stated in *Economics of Good and Evil* [95], "Economics (and science in general)…wants to know much in *certain things*, but in the moral area it wants to know nothing." Economists, like many engineers, seek a value-free existence. As highlighted here, trickle-down engineering is not value free, and the extent to which its values align with an ever-changing engineering profession is a highly politicized question. It is time to turn up the volume of that debate.

Statement on the use of AI: The author used computing tools that draw on large language models, colloquially termed AI, to write this paper. These included contextual search for relevant literature including inciteful.xyz and ScholarGPT 4o under a paid subscription. The lead author additionally set up a Zotero MCP server on his local machine to enable customized contextual searches and inquiries of his Zotero library. All valid citations were downloaded as PDF documents into the Zotero library (to ensure authenticity due to the well-known hallucinations of AI) and also Google Notebook LM to allow rapid searches and queries. Beyond the tools pre-built into Microsoft Word no AI tools were used in outlining or writing the paper nor were such tools used to review or edit the submitted manuscript.

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