Bargaining, Bartering, and Price Rigidity in Corporate Contracting

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Significant corporate transactions (such as financing and acquisition agreements) are typically negotiated in stages, wherein core pricing terms are fixed early while most non-price provisions are relegated to subsequent bargaining. This ordering stands in stark (and curious) contrast with canonical theories of contract design, which overwhelmingly counsel that non-price terms should be fixed first, saving price negotiations for last so as to fine tune the parties' net payoffs. This longstanding disjunction between theory and practice has become a celebrated puzzle for transactional design. We present an analytic framework that helps to reconcile the two, marrying a bargaining model and a search game over innovative contractual provisions. Our framework delivers a robust and tractable set of intuitions about when fixing price before other terms optimally incentivizes strategic search investments by the contracting parties. Our analysis is also amenable to making counterfactual comparisons of regimes where price is (and is not) set first, generating in the process several empirically testable implications.

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In theory, there is no difference between theory and practice...

...while in practice, there is.

1 Introduction

The aphorism above has a notoriously contested provenance,[1] but its underlying insights are hard to gainsay. One need not venture far into myriad academic fields to discover a landscape riddled with famous (if not spectacular) collisions between theory and practice. Examples abound across topical domains such as education, labor, health, engineering, software, environmental policy, and medicine. In the light of these collisions, the aforementioned maxim represents an important cautionary tale about the dangers of siloed thinking, admonishing theorists to be ever mindful of institutional detail while chiding practitioners continually to revisit ossified practices that might have outlived their (long-forgotten) purposes.

The theory / practice disjunction is perhaps no starker than its occurrence (and recurrence) in high-stakes corporate transactions, such as acquisition and financing agreements. These contracts are amongst the longest, most contemplated, and most heavily negotiated in modern markets, and their sophisticated designers pour considerable energy into calibrating transactional structures. On the theory side, few subfields of economics are as well developed as optimal contract design. Much ink has been spilled on the topic during the last eight decades, garnering multiple Nobel prizes[2] and suffusing pedagogy across economics departments, business schools and law schools alike. Given the appreciable economic stakes and the sophisticated players involved, large corporate transactions would seemingly be an ideal proving ground for contract design theory. Indeed, if there is *any* area where contract negotiators might behave like the strategic rational actors in a canonical economic model, this is surely it.

And yet, the norms and protocols of practitioners who structure large corporate transactions have long diverged in a substantial way from fundamental tenets of contract design theory: in short, both sides regard the other as operating "backwards" in positing the price and non-price terms of a deal. According to conventional contract theory, price is a perfectly adjustable zero-sum mechanism—the consummate numeraire that fluidly transfers payoffs between parties in a welfare-neutral manner. Non-price terms, in contrast—such as covenants, conditions, warranties, and the like—are rarely zero-sum, and their contractual allocation has real welfare consequences.

1. This excerpt is widely (and erroneously) attributed by turns to Yogi Berra, Albert Einstein, Richard Feynman, Nassim Taleb, and several others. The earliest use of this phrase we can find appears far older still. See Benjamin Brewster, *Portfolio*, Yale Literary Magazine 416:202 (1882).

2. In the last thirty-five years alone, Nobel laureates specializing in contract theory include Milgrom and Wilson (2020), Hart and Holmstrom (2016), Tirole (2014), Roth and Shapley (2012), Hurwicz, Maskin and Meyerson (2007), Mirrlees and Vickrey (1996), Harsanyi, Nash and Selten (1994), and Coase (1991).

Accordingly, efficiency calculus counsels that non-price provisions should be structured first (prior to setting price), with a goal of maximizing expected joint surplus. Only after those terms are fixed should pricing enter *at the very end* of the process. Such a sequence makes eminent sense (at least in theory), since the transfer-payment aspect of price makes it an ideal tool for truing up any payoff imbalances left behind after aggregating the joint welfare maximizing non-price terms, "greasing the wheels" of a mutually beneficial optimal contract. This sequential prediction is so fundamental and well-supported, in fact, that it permeates virtually all of contract design theory (*See* Bolton and Dewatripont 2004).

Nevertheless, and in stark contrast with contract theory, much transactional practice typically proceeds in the reverse direction, fixing core price terms at the very beginning, often via a succinct term sheet produced *ab initio* by executives and insiders.[3] Only after pricing is locked in does a coterie of outside lawyers and other transactional specialists sweep in to hammer out the non-price details. While these latter actors have significant latitude to structure terms, one thing they are almost *never* permitted to do is to revisit pricing: Although price re-cuts sometimes happen, they are heavily discouraged by a variety of institutional factors, and are therefore extremely rare.[4] Put simply, the practice of fixing price at the onset of bargaining means that transactional professionals are left with the task of assembling the remaining non-price components with nary a drop of the transactional grease that price adjustments can (theoretically) afford.

The persistent deviation of contract theory (fix price last) from transactional practice (fix price first) has long puzzled scholars and practitioners, sparking debate and inquiry into why price—which is otherwise an ideal payoff re-leveling mechanism—remains an inflexible anchor on negotiations, especially in the realm of large corporate transactions where the monetary stakes are appreciable. Compounding this quandary further, perhaps, is a different norm in smaller transactions (such as used car sales or residential real estate) where—consistent with theory—pricing decisions typically remain more fluid throughout the negotiation process. Why would such contracts tend to conform to theoretical predictions while large corporate transactions (with billions of dollars at stake) diverge?

This paper seeks to reconcile theory and practice—for theoreticians and practitioners alike—by amalgamating a contract negotiation framework with a search model. The key to our approach is to analogize contract design to a production process (Choi, Gulati, and Scott 2021; Choi et al. 2022), whereby the choice set of non-price terms available to the parties is an endogenous product of the parties' efforts, for which they bear private and non-contractible costs. Within our

3. Note that some M&A sales processes, namely competitive auctions, are more amenable to non-price terms being set first, though even then not entirely so, as many auction processes allow bidders some degrees of freedom to adjust nonprice terms.

4. Price renegotiation in the LVMH-Tiffany transaction is a highly-publicized exception to the rule, as described in Jennejohn, Nyarko, and Talley (2022). This broader phenomenon of reference dependence in shaping economic outcomes is discussed in O'Donoghue and Sprenger (2018); other work on the role of similar benchmarks or expectations in two-stage bargaining settings includes Crawford (1982), Muthoo (1992), and Basak and Khan (2024).

framework, fixing the deal price at the onset can emerge as an efficient design choice, both from an incentive compatibility perspective and for joint surplus maximization. In particular, we show that fixing price first can better incentivize parties towards efficient search for and production of welfare-enhancing non-price terms, a sort of two-sided "hostage-taking" in the spirit of Williamson (1983). Moreover, to the extent that uncovering creative non-price provisions has greater value in high-stakes environments, our model predicts that "price-first" bargaining will tend to be more prevalent in large corporate transactions than in smaller-stakes deals.

The intuition behind our argument unfolds in four key steps. First, we posit (realistically) that contracting parties are heterogeneous, and thus the optimal contract terms for a randomly chosen set of counterparties may differ from some other randomly chosen dyad. Second, we assume (again realistically) that bargaining power is an exogenous primitive, which cannot itself be bargained over. That is, if a negotiating party possesses the lion's share of the bargaining power, they cannot commit *not* to use that power at a later stage. Third, we argue that the universe of possible non-price terms (beyond standard-form "boilerplate" templates) is not obvious ex ante; rather, finding a bespoke non-price term that enhances payoffs requires discretionary and costly search process, undertaken by at least one of the parties.

Fourth, and critically, we posit that the most skilled searcher for non-price terms need not also be the best negotiator. Thus, when search ability and bargaining power are not aligned, fixing price last (as conventional theory counsels) can disincentivize efficient search. The reason is simple: because the costs of searching for welfare-enhancing non-price terms will become sunk once such terms are unveiled, those efforts quickly become irrelevant in the last stage when the parties bargain over price; instead, the bargaining outcome from that point forward hinges centrally on each party's relative bargaining power. As such, a party contemplating searching for innovative non-price terms faces the prospect that even if she succeeds, her counterparty will marshal superior bargaining power to extract the newly-created value through pricing concessions, leaving the searcher holding little more than an empty bag (and a sunk cost). The searcher's anticipatory concern over expropriation becomes especially acute, moreover, as the non-searching party's relative bargaining power increases.

When, in contrast, price is fixed from the onset, the parties' search incentives change fundamentally, typically in the direction of *more* efficient search. When (for example) the most efficient searcher has little relative bargaining power, the rigidity of a fixed-price term sheet metamorphoses from a bug into a feature,[5] incentivizing her to work harder to find a value-enhancing non-price term without fear that her counterpart will later expropriate the added value by wheedling on price (which is now no longer permitted). Moreover, even when the searching party also possesses significant relative bargaining power, her incentives remain roughly unchanged regardless of whether price is set first or last: in either case, she will be able to capture most of the value she brings to

5. *Compare* Franz Kafka, Metomorphosis (1915).

the table from a successful search. Aggregating across cases, our theoretical framework predicts that in a "large" set of parametric environments, fixing price ex ante can catalyze more efficient production of non-price terms overall, resulting in more advantageous expected outcomes for both parties.

More generally, our analysis illustrates the counter-intuitive possibility for creating value by transforming a seemingly frictionless bargaining problem with low transaction costs into a more rigid bartering problem, where the only available currency for negotiated exchange is by "horse trading" the newly-discovered non-price terms. Thus, while fixing price *ab initio* no doubt introduces certain transactional frictions, it can simultaneously promote efficient incentives, resulting actuarially in new, welfare-enhancing non-price terms that would have been unlikely absent a locked-in price.

In addition to developing a theoretical model capable of reconciling the longstanding disjunction between theory and practice, we also make three contributions to the contract theory literature. First, we develop a search framework in two dimensional space—value to the buyer and value to the seller—centered at the values of the ex ante standard form contract. Using polar coordinates we reduce the search decision of the buyer and seller to a decision over two variables: (1) the direction of search (measured by degrees on the unit circle) and (2) the intensity of search (measured by the length of the ray of the targeted search). By reducing the optimization problem of both buyer and seller to these two dimensions, we develop a tractable and powerful framework that we believe can be deployed and extended in other contexts like trade negotiations or exclusive contracting in labor or real estate. These settings differ from smaller transactions in which the typical price-last formula is followed, highlighting the role of actively creating value-enhancing contract terms in these larger transactions.

Second, we embed a discrete bartering model (over contract terms in stage 2) into a Nash bargaining model (over prices, in stage 1). This unlikely marriage reflects what happens in real world high stakes transactions, but at the theoretical expense of introducing discontinuities that undermine the tractability of the model. Despite these challenges, we are able to find closed form choice probabilities under certain simplifying assumptions and simulate numerical solutions across a full range of parameter values in our model. We do this by using a choice probability approach taken from the discrete choice literature (see e.g. McFadden 1972; Berry, Levinsohn, and Pakes 1995; Eaton and Kortum 2002), under the assumption that deal-specific heterogeneity makes the proposed contract terms vary in their suitability across deals. This has the added bonus of making the analysis of more complex contracts (with various discrete terms which are themselves the result of negotiations) empirically tractable using standard tools from industrial organization. While other studies of bargaining leverage detailed data on alternating offers (Backus et al. 2020; Dunn et al. 2024), this approach is particularly suited to settings with simultaneous and/or unknown procedures for contract development.

Third, we develop a standard sister Nash bargaining model with bartering in stage 1 and price setting in stage 2. This model formalizes the standard intuition for setting price last but highlights its dangers in the setting where contract terms must be created instead of being given exogenously. That is, the timing of this contracting game means that non-contractible efforts to develop contract terms before the price is fixed are sunk, leading to a two-sided analogue the holdup problem in Klein, Crawford, and Alchian 1978. Moreover, the similarity between the two models enables us to compare various outcome values across the competing models. This comparison yields both empirical predictions and an explanation that reconciles the disjunction between practice and the currently prevailing theoretical models: setting the transaction price first, in many settings, incentivizes more efficient search for contract terms.

The account we offer here does more than reconcile theory and practice, however. It also sheds light on a variety of other norms that are commonly observed in large-stakes deal negotiations as well as important legal doctrines. For example, a direct implication of our theoretical approach is the possibility of deal failure. In our model, bargaining parties may rationally sign up a deal using standard "boilerplate" terms that, at least when signed, actually makes one/both of them worse off than their status quo payoffs without a contract. Why would they do so? Because they expect, in equilibrium, that the ensuing search for non-price terms would yield new provisions that enhance their individual welfare levels so as to make closing the deal a joint improvement.

In a similar vein, our approach reveals a plausible rationale behind enforcing even preliminary agreements that do not have all their key terms locked in (sometimes known as "Type II" agreements). This is an area where courts have grown increasingly willing to deploy enforcement tools (such as reliance or expectation damages) against a party who fails to deploy "good faith" efforts to finalize the terms of a preliminary agreement.[6] Fixing price ex ante in our framework is important precisely in situations where it is important to incentivize parties to expend good-faith efforts to find value enhancing terms. A party's failure and/or refusal to do so can be particularly harmful in our setting, since it can increase the odds of wasteful deal failure. Consequently, courts' enhanced willingness to enforce "Type II" agreements can be interpreted as consistent with catalyzing efficient search incentives within our model.

Our account also yields predictions about the nature of the search for non-price terms. Significantly, our model gives the parties considerable discretion about what "direction" (in payoff space) to conduct their search. We show that in a large (and plausible) family of equilibria, the parties will tend to avoid engaging in purely "selfish" search, seeking terms that benefit themselves alone with no benefit (or negative benefit) to their counterparty. Selfish search is risky in our model, since any "bartering" of non-price terms (with no prospect of a price adjustment) must result in a Pareto improvement over the baseline boilerplate agreement to survive. A selfish search is destined to fail this test when analyzed alone; its prospective utility, then, is critically dependent on being

6. *Compare* Empro v. Ballco, 870 F.2d 423 (7th Cir. 1989) *with* Siga v. PharmaThene, 67 A.3d 330 (Del. 2013), Pennzoil v. Texaco, 481 U.S. 1 (1987), Copeland v. Baskin Robbins, 96 Cal.App.4th 1251 (Cal. Ct. App. 2002).

combined with another discovered term so that their aggregation results in Pareto improvement over the boilerplate. While possible, such combinations are not reliably rendered in equilibria of our model, and in any event they require significant coordination to produce. In contrast, it tends to be more lucrative for each party to search for non-price terms in a (weakly) unselfish manner, so as to ensure any term they uncover represents an acceptable Pareto improvement over the default.

Finally, our model helps reveal the critical importance that good lawyering can play in transaction design. Highly skilled lawyers in our model face lower search costs, plausibly reflecting a combination of greater creativity and more robust firm-level experience (their own and their partners). Consequently, good lawyers are also more skilled at smoking out value-enhancing non-price terms, which in turn expands the frontier of payoff possibilities that are available in equilibrium. In fact, when two high quality firms interact with one another, they may be in a better position to coordinate their searches, producing non-price terms that—while not individually Pareto improving—become strongly welfare enhancing when combined as part of a bartered *quid pro quo*.

Although we are not the first to observe the odd disjunction between the theoretical account of optimal contracting (where price is chosen last) and the practical reality (where price is fixed first), our framework is novel in several respects. For instance, our model provides microfoundations for observed phenomena, such as Badawi and Fontenay (2019)'s of the "first mover" advantage in the design of non-price M&A terms. It also advances earlier efforts that explored the roles of bargaining power and asymmetric information on the design of non-price terms in M&A contracts (Choi and Triantis 2012) by introducing the contractual innovation process—the non-trivial search for new terms in the context of a particular design problem (Jennejohn, Nyarko, and Talley 2022)—into its core model. Our model also uses existing tools from the literature on empirical choice models to present an empirically tractable model that can be used to analyze the value of chosen contract terms, even when there is no post-negotiation variation in price. This empirical tractability extends to other settings where firms or other agents may jointly choose among discrete options.

Our analysis unfolds as follows. In Part 2, we provide relevant context for the development of contracts in corporate transactions. In Part 3, we present the overview of our baseline model, with additional details deferred to Appendix 1. In Part 4, we describe the model's solution and present various comparative statics. Part 5 considers extensions to and modifications of the baseline model. Part 6 concludes.

2 Contract production in the M&A market

The modern M&A agreement is a complex piece of transactional technology, typically encompassing over 100 pages of obligations (Coates 2016; Jennejohn 2018; Hwang and Jennejohn 2018).[7] While many markets cope with similar levels of contractual complexity by standardizing terms across deals

7. Often, ancillary agreements are also attached to the main agreement (Hwang 2016). Our focus here is on the main M&A agreement that accomplishes the core transaction.

(Gulati and Scott 2012), M&A agreements are surprisingly resistant to rote use of boilerplate, and a significant amount of transaction-specific tailoring of terms often occurs in each negotiation (Coates 2016; Jennejohn 2020). In short, there is space for creativity for the transaction designer, and, indeed, reputational benefits accrue to advisors who successfully innovate effective new terms.

The terms of these complex contracts can be sorted into the following key categories. First, the operative terms of the agreement set forth the details of how the business combination will be accomplished, including the price for the acquisition and the nature of the consideration used (cash, the acquirer's stock, or a combination of the two). Second, the seller provides a series of representations and warranties relating to, most notably, the qualities of the target company, thereby addressing potential risks that are unobservable during the acquirer's due diligence process.[8] Third, a series of covenants, which apply to the behavior of either (or both) acquirer or seller between the time the contract is executed and the time the transaction closes,[9] address pre-closing risks, such as: interim operating covenants that require the seller to operate the target in the ordinary course of business, thereby precluding extraordinary decisions that would impair the value of the target company; regulatory provisions that address the possibility of, for instance, an antitrust or national security regulator attempting to prevent or force the restructuring of the transaction; and deal protection devices, like "no-shop" provisions, that constrain the seller's ability to pursue alternative bids. Fourth, and finally, conditions to closing and termination provisions connect breaches of the aforementioned terms to the parties' duty to close the transaction, thereby incentivizing performance.

To make that complexity manageable, the advisers to a transaction—the investment bankers and deal lawyers advising both buyer and seller—will bifurcate the negotiation process into two steps. First, the key operative—or "business"—terms, including the price and a smattering of important terms across the four categories above, are determined and reduced to a preliminary agreement, such as a term sheet or letter of intent. The principals of both buyer and seller are heavily involved at this stage since, as one hoary treatise in the field notes, "the usual topics of discussion at the outset are generally basic business areas, on which attorneys should defer to their clients" (Freund 1975). Second, once the core business terms are preliminarily agreed upon, the detailed "legal" terms of the agreement are then hammered out. Here, the division of labor shifts, with the deal lawyers taking the wheel.

As a practical matter, the price and other key terms set in the first step of the negotiating process are typically quite sticky. Detailed examples of such stickiness are infrequently available in the public record, since secrecy in merger negotiations is jealously kept. However, they arise from time to time in, for instance, deals that break down and are subject for litigation. For instance, the

8. The buyer also typically provides a series of representations and warranties focused primarily upon its ability to execute the transaction, but these are usually less negotiated.

9. For most large, complex transactions, a period of time between signing and closing is necessary in order to allow, for instance, for regulatory reviews or shareholder approvals.

M&A deal at the heart of *Frontier Oil v. Holly* provides a glimpse of how resistant the initially-set price term can be to change.[10] That transaction involved, among other assets, the acquisition of an oil rig that had been sitting on the grounds of Beverley Hills High School for decades. When the negotiations were far advanced, news broke that none other than Erin Brockovich had announced plans to bring a mass toxic tort suit against one of the target company's subsidiaries, which operated the rig that allegedly harmed students. That potential liability risk had not been disclosed during due diligence, despite similar cases resulting in settlements worth hundreds of millions of dollars. Instead of revisiting the purchase price in light of the revelation though, the parties reworked a series of detailed terms in the agreement, resolutely remaining in the second—legal—stage of the negotiating process rather than going back to square one.

In the next section, we introduce a model that explains why this curious approach to contract design is pursued, shedding light on market practice and, in turn, informing the legal system's approach to enforcing contractual obligations as they emerge in this negotiating process.

3 A model of two-stage contracting

In light of industry practice of set price first and barter over terms second, along with the importance of deal term innovation in complex merger agreements, in this section we build out a novel, tractable model that both mirrors industry practice and incorporates term innovation. We begin in Subsection 3.1 by describing the transaction in the model (the sale of an asset from a seller to a buyer) that involves three steps, the order of which will change depending on the model: (1) the parties set the price, (2) the parties search for new terms, and (3) the parties select the other terms of the contract based on the return of each party's search. In Subsection 3.2 we present the model in which price is set first, the search for other terms is second, and bartering over other terms occurs third. In Subsection 3.3 we present the model in which search for other terms occurs first, bartering over other terms occurs second, and price is set last. Once both models are fully laid out, we then, in subsequent sections, compare closed form solutions across the two models in a restricted case and numerical solutions in the general case.

3.1 Term innovation and alternate sequencing

Consider a potential transfer of a "business asset" from a representative seller s to a representative buyer b. Each respective party places a valuation of π_i on the asset (where $i \in \{b, s\}$), and we assume these valuations to be common knowledge amongst the parties. The buyer's bargaining power is represented by an exogenous parameter $\tau \in (0, 1)$, and thus the seller enjoys complementary bargaining power $1 - \tau$.

To transfer the asset, the parties must enter a contract that consists of a price p paid from b to s, as well as a vector of non-price terms m. The non-price terms collectively give rise to an additional

10. See Frontier Oil Corp. v. Holly Corp., 2005 WL 1039027 (Del. Ch. April 29, 2005).

expected value $v_i(m)$ to each party i, independent of (and in addition to) the parties' individual valuations π_i. Because our key results hinge on strategic dynamics within payoff space, our analysis need not characterize the full vector space of all non-price terms; we instead characterize any non-price term vector m by the expected payoffs it conveys to the parties, $v(m) \equiv (v_b(m), v_s(m)) \in \mathbb{R}^2$. With one exception, the non-price terms are assumed hidden from the parties, and discovering them requires costly search (described below). The sole exception is a "default" (or "standard form") set of non-price terms m_0, which are commonly known. We normalize the coordinates of m_0 in payoff space to be at the origin, and thus the expected payoffs it conveys to the parties are normalized at $v_i(m_0) = 0$ for $i \in \{b, s\}$.

For exposition purposes, it will frequently prove convenient to characterize non-price terms in payoff space using polar coordinates, with radius $r \in \mathbb{R}_+$ and angle $\theta \in [0, 2\pi]$. To further economize on notation, it will also be convenient to transform θ into $\theta(a) \equiv \pi(a + 0.25)$, where $a \in [-1, 1]$. Thus, the contract terms create values

$$v_b(m) = r\cos(\theta(a))$$
$$v_s(m) = r\sin(\theta(a))$$

The final contract terms are chosen from the subset $\mathcal{M}^*$ of terms that are known to both firms at the time of bargaining–which include by default the standard-form terms m_0, any other non-price terms discovered by the parties, and the combination of such terms).

Prior to negotiation, each party i can search for one new term m_i. The parties' search decisions are made simultaneously, and search efforts are assumed (at least for now) to be non-contractible. When each player uncovers a new term m_i, that new price vector's coordinates in payoff space are added to the choice set of possible non-price terms. Since both parties search, the choice set minimally expands further to $\mathcal{M}^* = \{m_0, m_b, m_s\}$. We also assume jointly discovered terms can be combined additively, so that the choice set expands even further to $\mathcal{M}^* = \{m_0, m_b, m_s, (m_b + m_s)\}$; we write the latter term as m_{bs}.[11] Thus, each set of contract terms in $\mathcal{M}^*$ is indexed by the subscript j where $j \in \{0, b, s, bs\}$.

Each player faces a cost $c_i(r_i, a_i)$ to search for non-price term innovations. The cost is assumed to be continuously differentiable, increasing and convex in search intensity r_i, but with $\frac{\partial c_i(0,a_i)}{\partial r_i} = 0$ so search is costless on the margin near the default contract. Costs are assumed to be weakly decreasing in $|a_i|$, so it is costlier to search in directions that are increasingly Pareto improving and

11. The technology for combining terms is assumed linear in the expected payoffs, i.e. $v_i(m_{bs}) = v_i(m_b) + v_i(m_s)$. Using the polar form, the new contract bs is characterized by

$$r_{bs} = \sqrt{r_b^2 + r_s^2 + 2r_b r_s \cos(\theta(a_s) - \theta(a_b))}$$
$$a_{bs} = \frac{1}{\pi}\left[\theta(a_b) + \tan^{-1}\left(\frac{r_s \sin(\theta(a_s) - \theta(a_b))}{r_b + r_s\cos(\theta(a_s) - \theta(a_b))}\right)\right] - 0.25$$

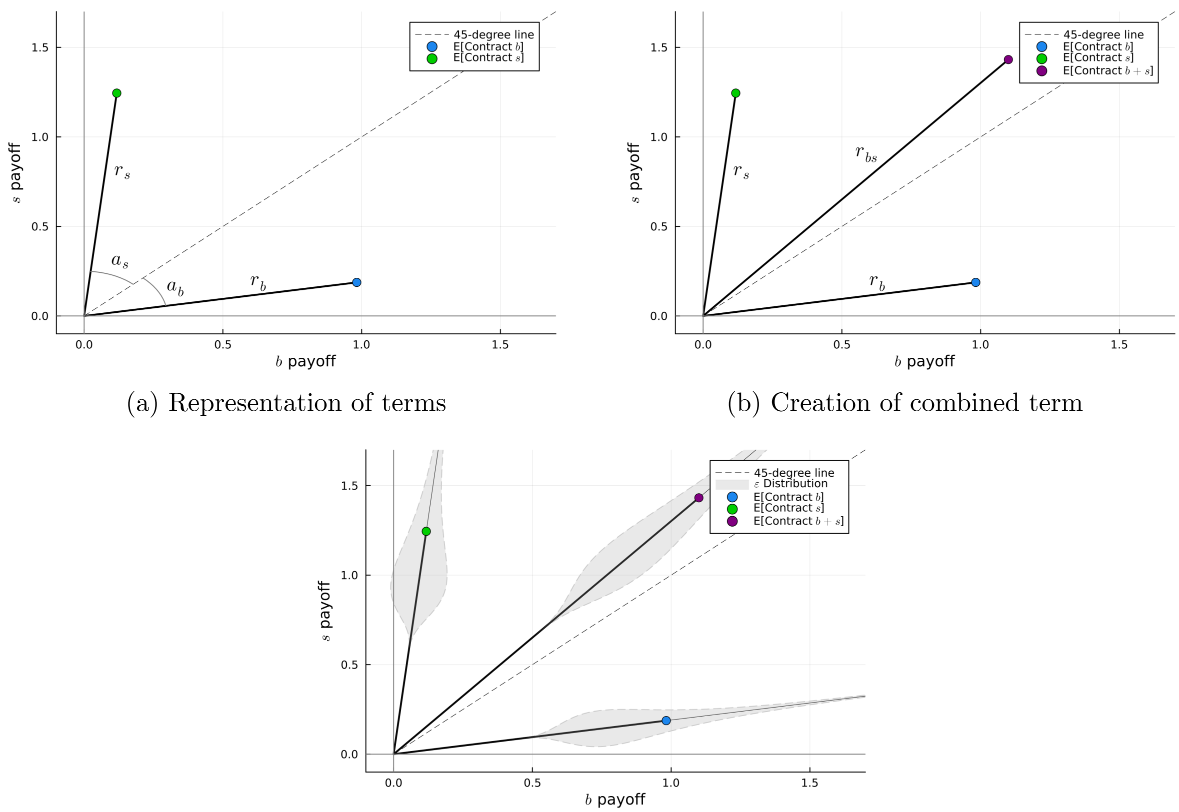
joint-surplus improving.

We also allow for *ex ante* uncertainty in firms' ultimate success in producing a new term conditional on search intensity. This assumption mimics real-world variation in the challenge of finding new terms, since both search productivity and term values may vary across deals in difficult to observe ways. (This uncertainty also may apply to attempts to combine discovered terms, as the firms' success in combining potentially-conflicting terms may also differ across deals.) To capture this uncertainty, we denote the realized search radius for term m_j as $r_j \cdot \epsilon_j$ with $\mathbb{E}[r_j \cdot \epsilon_j] = r_j$. We call ϵ_j a term-specific productivity shock that is only observed after investment decisions $\{r_i^*, a_i^*\}$ are made. This implies that realized payoffs, denoted $v_i(m_j; \epsilon_j)$, are in expectation equal to the average payoffs $v_i(m_j)$ defined above.[12]

Before proceeding, we provide some graphical intuition for the set of possible contracts in the payoff space. In Figure 1, each component is added sequentially to build a representation of the possible choices of contract terms. Panel (a) first shows two sample contracts in payoff space, using the respective radii and search angles (recentered around the 45-degree line) to characterize each. Panel (b) then adds the expected payoff of the combined term, and panel (c) further illustrates the uncertainty in term production by representing the payoff as a point along a ray, with the associated density of ϵ plotted along each ray. Though the expectation of the contract term payoff is determined by the choice of r_i^* and a_i^*, the realization of each contract will fall somewhere along its corresponding ray.

12. Note that while expected payoffs are linear in the component payoffs (i.e., $v_i(m_{bs}) = v_i(m_b) + v_i(m_s)$), the same does not hold for realized payoffs. We interpret ϵ as a shock to the firms' ability to implement the term in an actual contract, noting that frictions in the contract negotiation process may complicate the process of combining two distinct terms.

Figure 1: Contract term components in firm payoff space



(a) Representation of terms

(b) Creation of combined term

(c) Uncertainty in term production along angle of search

Notes: Each panel plots components of the contract term model to illustrate the choice set in payoff space. Successive panels add more features of the search game, but remove some notation to highlight the new features. Panel (a) begins with the payoffs of the proposed firm contract terms, and panel (b) adds the combined contract term from using both firms' terms. Panel (c) plots densities around the search radii corresponding to the densities of each term-specific shock ϵ, where the mean contract value is at the colored dots first plotted in the preceding panels.

With this framework in mind, we consider two possible games that are differentiated by when the two pieces of the contract are created. In the "price-first" game (PF) firms determine the price p^*_{PF} via Nash bargaining before producing new terms $m_{i,PF}$ and bargaining over which terms m^*_{PF} to select. In the "price-last" game (PL) firms invest in and choose the contract terms m^*_{PL} and then the deal price p^*_{PL}. The productivity draws associated with the chosen contract in the two games are ϵ^*_{PF} and ϵ^*_{PL}.

Table 1: Timing of the two games

t	Price-first	Price-last
0	b and s decide to transact	b and s decide to transact
1	p^*_{PF} is chosen	$\{r^*_{i,PL}, a^*_{i,PL}\}$ are chosen
2	$\{r^*_{i,PF}, a^*_{i,PF}\}$ are chosen	m^*_{PL} is chosen
3	m^*_{PF} is chosen	p^*_{PL} is chosen

We now examine in detail how the prices and contract terms are determined in the two games. The timing of the two games is summarized in Table 1. Prices in both games are determined via Nash bargaining over expected equilibrium payoffs given available information when the price is chosen. We also assume the chosen contract maximizes the weighted Nash product of firms' continuation payoffs at the contract term stage. This is similar to the standard Nash bargaining framework (Nash 1950) but with a discrete choice set $\mathcal{M}$ rather than a convex choice set; we call this Nash *bartering* to emphasize this distinction. While this modified framework does not have all the guarantees of standard Nash bargaining (in particular, the relationship of non-cooperative and cooperative bargaining), it provides a concise framing of the term bartering stage without taking a stand on the timing and rules of a sequential bargaining game.[13]

3.2 Contract creation in the price-first game

We now study the timing of the price-first contract game. We proceed by backward induction, first considering how contract terms are chosen, then firms' choice of term production, and lastly the price bargaining game.

Bartering for terms. Since the contract price is fixed (under the default contract with standardized values $v_i(m_0) = 0$) before contract terms are chosen, the firms choose whichever term out of $\mathcal{M}^*$ yields the greatest Nash product:

$$\begin{aligned} m^*_{PF} &= \underset{m_j \in \mathcal{M}^*}{\text{argmax}} \quad (v_b(m_j)\epsilon_j)^{\tau} \cdot (v_s(m_j)\epsilon_j)^{1-\tau} \\ &= \underset{m_j \in \mathcal{M}^*}{\text{argmax}} \quad \underbrace{\left[v_b(m_j)^{\tau} \cdot v_s(m_j)^{1-\tau}\right]}_{\delta_{j,PF}} \cdot \epsilon_j \\ &= \underset{m_j \in \mathcal{M}^*}{\text{argmax}} \quad NP_{j,PF} \\ s.t. &\quad v_i(m_j) \geq 0, \quad i \in \{b, s\} \end{aligned}$$

The non-negativity constraint holds because neither firm will accept a contract term that reduces their individual surplus.[14] We also emphasize that the set of possible terms $\mathcal{M}^*$ that is considered

13. See Appendix A1 for a more detailed discussion of the relationship of this model to standard Nash bargaining.
14. For the price-first game, this assumption functionally implies that neither party is made worse off than their status quo ante should a preliminary deal fail – so that neither party would become "damaged goods."

under bargaining is itself an equilibrium object that was previously decided by firms' investment decisions. We consider this choice now.

Search for terms. Firms choose their search angle a_i and search radius r_i to maximize their expected net payoff from the term bartering stage. Each term-specific shock ϵ_j is crucial in determining which contract term is chosen, but these are not realized until after firms' decisions are made. Thus, the expected payoffs depend both on the Nash program in the term-bartering stage and the joint distribution of ϵ, which we leave unspecified for now.

$$\{r_i^*, a_i^*\} = \underset{r_i, a_i}{\operatorname{argmax}} \quad \mathbb{E}[v_i(m^*; \epsilon^*) \mid m^* \text{ is chosen in game } PF \text{ from } \mathcal{M}^*] - c_i(r_i, a_i)$$

We write the equilibrium expected term-specific payoff (conditioning on the equilibrium firm choices r_i^* and a_i^*) as $U_{i,PF}^*$. These expected payoffs, and their associated costs, are considered by the forward-looking firms when deciding on the contract price.

Bargaining for prices. Firms use their expected equilibrium net payoffs $U_{i,PF}^* - c_i(r_{i,PF}^*, a_{i,PF}^*)$ in the continuation game as a reference point when bargaining. The equilibrium price is determined by

$$\begin{aligned} p_{PF}^* &= \underset{p \in \mathbb{R}_+}{\operatorname{argmax}} \quad (\pi_b - p + U_{b,PF}^* - c_b(r_{b,PF}^*, a_{b,PF}^*))^\tau \cdot (p - \pi_s + U_{s,PF}^* - c_s(r_{s,PF}^*, a_{s,PF}^*))^{1-\tau} \\ &= \tau(\pi_s - U_{s,PF}^* + c_s(r_{s,PF}^*, a_{s,PF}^*)) + (1-\tau)(\pi_b + U_{b,PF}^* - c_b(r_{b,PF}^*, a_{b,PF}^*)) \end{aligned}$$

In other words, the firms split both the expected surplus from the sale of the asset and the expected net surplus created by new contract terms according to their relative bargaining power.

3.3 Contract creation in the price-last game

We now study the timing of the price-last contract game. We proceed by backward induction, first considering how the price is set given contract terms, then how the contract terms are chosen, and lastly the firms' choice of term production.

Bargaining for prices. The contract price is chosen only after the contract terms are decided and the cost of finding these terms is sunk. Thus, the price for any chosen terms m_{PL}^* (with the associated shock ϵ_{PL}^*) is:

$$\begin{aligned} p_{PL}^* &= \underset{p \in \mathbb{R}_+}{\operatorname{argmax}} \quad (\pi_b - p + v_b(m_{PL}^*; \epsilon_{PL}^*))^\tau \cdot (\pi_s + p - v_s(m_{PL}^*; \epsilon_{PL}^*))^{1-\tau} \\ &= \tau(\pi_s - v_s(m_{PL}^*; \epsilon_{PL}^*)) + (1-\tau)(\pi_b + v_b(m_{PL}^*; \epsilon_{PL}^*)) \end{aligned}$$

That is, setting the price after terms are decided means that firms negotiate the price to split the newly created value from the contract.

Bartering for terms. Both firms know that the price chosen in the last stage of the game splits the surplus from the contract according to each firm's relative bargaining power. Thus, the firms choose the terms that solve the Nash program:

$$\begin{aligned}
m^*_{PL} &= \underset{m_j \in \mathcal{M}}{\text{argmax}} \quad [\tau(v_b(m_j) + v_s(m_j))\epsilon_j]^{\tau} \cdot [(1-\tau)(v_b(m_j) + v_s(m_j))\epsilon_j]^{(1-\tau)} \\
&= \underset{m_j \in \mathcal{M}}{\text{argmax}} \quad \tau^{\tau}(1-\tau)^{(1-\tau)}[v_b(m_j) + v_s(m_j)] \cdot \epsilon_j \\
&= \underset{m_j \in \mathcal{M}}{\text{argmax}} \quad \underbrace{[v_b(m_j) + v_s(m_j)]}_{\delta_{j,PL}} \cdot \epsilon_j \\
&= \underset{m_j \in \mathcal{M}}{\text{argmax}} \quad NP_{j,PL} \\
s.t. &\quad v_b(m_j) + v_s(m_j) \geq 0
\end{aligned}$$

Note that this program is equivalent to maximizing the combined surplus generated by the new contract terms, regardless of who benefits from that term. As in the price-first game, there is a non-negativity constraint implying that terms will only be considered if they are a net improvement over the default contract m_0.

Search for terms. Each firm chooses search angle a_i and search radius r_i knowing how both the final contract terms and price will be chosen. In this case, the firms choose to maximize their share of the expected joint surplus minus the cost from finding these terms.

$$\begin{aligned}
\{r^*_b, a^*_b\} = \underset{r_b, a_b}{\text{argmax}} \quad & \tau \cdot \mathbb{E}[v_b(m^*;\epsilon^*) + v_s(m^*;\epsilon^*) \mid m^* \text{ is chosen in game } PL \text{ from } \mathcal{M}^*] \\
& - c_b(r_b, a_b) \\
\{r^*_s, a^*_s\} = \underset{r_s, a_s}{\text{argmax}} \quad & (1-\tau) \cdot \mathbb{E}[v_b(m^*;\epsilon^*) + v_s(m^*;\epsilon^*) \mid m^* \text{ is chosen in game } PL \text{ from } \mathcal{M}^*] \\
& - c_s(r_s, a_s)
\end{aligned}$$

This stage differs from the firm problem in the price-first stage: instead of receiving the full benefit of their search, firms only receive a share of the combined firms' surplus from the chosen term. As in the price-first game, it is helpful to denote the equilibrium expected payoff to firm i from the chosen contract term as $U^*_{i,PL}$.

4 Characterizing the equilibrium contract

Thus far, we have laid out the basic components of the term search, contract term bartering, and price bargaining processes. At this level of generality, we cannot directly solve for firms' equilibrium choices because these depend on the distribution of term-specific productivity shocks ϵ and the term search costs c_i. We now study the model under additional restrictions in order to directly analyze the firms' decisions.

We introduce a set of simplifying assumptions on the term search stage that allows us to obtain closed-form solutions for firms' equilibrium strategies and directly compare the price-first and price-last models. The first two assumptions limit the direction of each firms' search and the correlation between their realized term values so that the equilibrium contract always incorporates terms proposed by both firms. The third assumption introduces a functional form for the convex investment cost function that pins down each firm's search decisions and allows us to take comparative statics with respect to each firms' relative bargaining power and term search costs.

After making these assumptions, we then consider two extreme cases in which we restrict each firms direction of search for new terms. In the first case, we restrict both firms to search for terms that are value-enhancing for themselves and value-neutral for the other firm (i.e., $a_b = -0.25$ and $a_s = 0.25$). We call this orthogonal, or self-interested, search. In the second case, we restrict both firms to search for terms that are equally value-enhancing for both themselves and the other firm (i.e., $a_b = a_s = 0$). This is called aligned, or surplus-maximizing, search. In both settings, firms can combine their terms to create a joint term m_{bs} that is considered along with the individual terms m_b and m_s. These two cases provide intuition for firms' behavior when their angle of search is exogenous, but neither restriction is necessary to pin down either firms' equilibrium strategies.

In both cases, the price-first model represents a weak improvement in total surplus creation over the price-last model. In the first case (orthogonal search), the price first model is Pareto optimal relative to the price last model for both firms across the full range of values for the unrestricted parameters. Notably, for interior values of the bargaining weight, this is a strict improvement for both firms. In the second case (aligned search) the price first model is Kaldor-Hicks optimal relative to the price last model across the full range of values for the unrestricted parameters. For all cases with equal search costs except the case with equal bargaining power, there is strictly more surplus created under the price-first model.

We then consider a third case in which we assume firms' search angles are endogenously determined but bounded. These bounds may arise due to professional norms or other constraints that prevent too "selfish" terms from being considered. This case provides additional intuition for firms' incentives when both their angle and direction of search are at least partially non-contractible: the price-first structure incentivizes more investment in novel contract terms than in the price-last game. When it is sufficiently costly to search for the most welfare-enhancing terms (i.e., along the 45-degree line, or $a_b = a_s = 0$), the price-first game creates more total surplus relative to the price-last game. More broadly, the two games yield different contracts in expectation as a result of the firms' differing incentives across the two games.

Finally, we discuss a generalization of this model that allows each firms' contract development efforts to affect the probability any individual terms are chosen, which in turn affects the expected payoff from the chosen contract. This generalization draws on standard tools in the discrete choice literature and allows for closed-form choice probabilities for each of the proposed contract terms. We allow for the firms' search for new contract terms to be unrestricted, though the firms' incentives to propose valuable contract terms lead them to behave similarly to the restricted setting.

This dominance of the price-first model in the first two cases and across a large range of values in the third case and generalized case is driven by properly incentivizing each firm's search for new terms. In the price-first model each firm captures more of their realized value of the discovered terms. In the price-last model, realized value of the discovered terms is redistributed based on the relative bargaining power of the firms, which leads to firms under-investing in their search for new terms. This difference is exacerbated when one firm is a more efficient searcher and can create more expected surplus than the other firm, regardless of the firms' relative bargaining power.

4.1 Simplifying assumptions and characterization of equilibrium search

In order to achieve tractability in our comparitive statics analysis, we begin by making the following simplifying assumptions regarding the term search stage:

A1 The direction of search is limited to the first quadrant so that all proposed contracts have weakly positive payoffs, i.e. $|a_i| \leq \bar{a} \leq 0.25$.

A2 The productivity shocks are perfectly correlated, i.e. $\epsilon_{bs} = \epsilon_b = \epsilon_s$.

Assumption **A1** introduces the possibility that firms can contract on the range of values for the angle of search a_i. The two case studied below present an even stronger contractibility setting where firms can contract on a precise angle a_i instead of a range. Although this contractibility may be difficult in practice due to the challenge of monitoring the other firms' efforts in contract creation, it provides a useful starting point to understand each firms' incentives to expend effort in creating a novel contract. Note that even in this setting, however, the multiplicative nature of the productivity shock ϵ_j means that firms cannot verify whether any realized contract value is due to the productivity shock or the other firm's ex ante selection of its search intensity. Thus, search intensity r_i is not verifiable and therefore not contractible in this restricted setting.

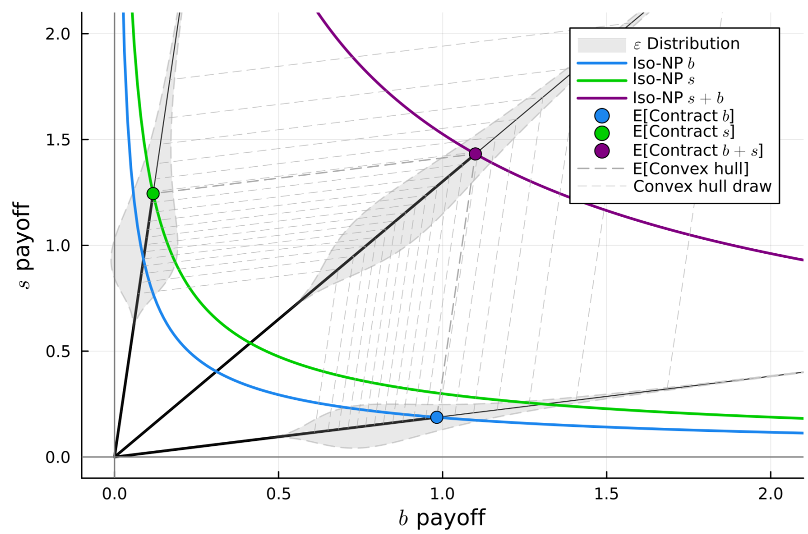
Assumption **A2** imposes that firms' individual and joint term production processes have the same shocks. This may occur because a particular deal faces some challenge that makes it difficult to decide contract terms more broadly (in the event of a low common productivity shock), or perhaps due to more willingness to accept non-boilerplate contract terms (for high productivity shocks). While perfect correlation in term productivity draws is a strong assumption, it simplifies the firms' expectations over term payoffs and emphasizes that the ability to innovate new terms is related to deal-specific factors. We relax this assumption in the subsequent section.

Under assumptions **A1** and **A2**, we have the orderings $NP_{bs,PF} > NP_{b,PF}, NP_{s,PF}$ and $NP_{bs,PL} > NP_{b,PL}, NP_{s,PL}$ for all $\tau \in (0,1)$, regardless of the choice of radii r_i. Thus implying

Lemma 1. Let **A1** and **A2** hold. Then both b's and s's contract terms are always incorporated into the final contract in both games.

An illustration of this is presented in Figure 2 for $r_b = 1$, $r_s = 1.25$, $a_b = -0.19$, $a_s = 0.22$, and $\tau = 0.4$ for the price-first game. The expected contract payoffs are plotted in the direction of search, along with the expected convex hull connecting them. Several other realizations of the convex hull are also plotted in lighter colors; these are all proportional because of assumption **A1**. The curves in Figure 1 represent the iso-Nash product lines, or the set of all contracts with equivalent Nash products. As shown in Lemma 1, the combined term yields a higher Nash product than the individual terms for any realization of ϵ.

Figure 2: Firm payoffs in the bartering stage of the price-first game (perfect correlation in ϵ)



Notes: None of these values necessarily represent equilibrium actions. Dashed lines represent possible convex hulls of the choice set of terms, for varying draws of ϵ with associated densities plotted around the ray corresponding to each contract as in Figure 1(c).

Lemma 1 has important implications for our analysis. First, it allows us to simplify the expected term-stage payoffs from the previous section as simply the expected term-stage payoffs from the combined term m_{bs}. Second, in both of the cases we next consider, it implies that each firm's choice of r_i is not affected by the other's search costs. Since firms' optimal search intensities are driven only by bargaining power and their own search costs, the following analysis holds even when γ_i is private information to firm i.

Together with general assumptions on the term cost function, these assumptions imply existence and uniqueness of each firms' investment equilibria in both the price-first and price-last games for given set of search angles a_i. They also allow for a relative ordering of each firms' search efforts between the price-first and price-last settings.

Proposition 1. Let **A1** and **A2** hold, and let a_i be fixed for $i \in \{b, s\}$. Further assume search costs $c_i(r_i, a_i)$ are increasing and strictly convex in r_i with $c_i(0, a_i) = 0$ and $\frac{\partial c_i(r_i,a_i)}{\partial r_i} |_{r_i=0}= 0$. Then

(i) the equilibrium of the term choice stage exists and is unique for both the price-first and price-last games.

(ii) the search radius for firm b is weakly higher in the price-first game than in the price-last game when $a_b \leq \frac{1}{\pi} \arctan(\frac{1-\tau}{\tau}) - 0.25$.

(iii) the search radius for firm s is weakly higher in the price-first game than in the price-last game when $a_s \geq \frac{1}{\pi} \arctan(\frac{1-\tau}{\tau}) - 0.25$.

(iv) in the price-first game, both firms search strictly less than is socially optimal except when $|a_i| = 0.25$, in which case both firms search at the socially optimal level.

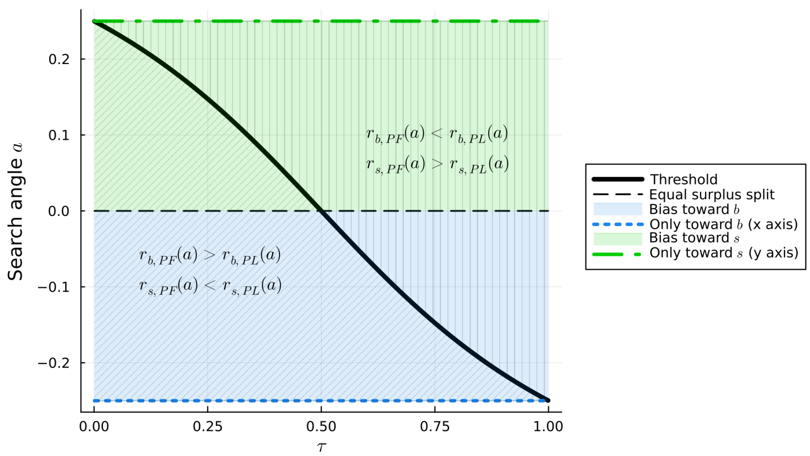
(v) in the price-last game, both firms search strictly less than is socially optimal except for when one firm has all the bargaining power ($\tau \in \{0, 1\}$), in which case only that firm searches at the socially optimal level.

(Proof in Appendix A2)

These results are straightforward: firms have a unique choice of search radius for any given search angle because of their convex search costs. However, this result allows for a direct comparison between the outcomes of the two different versions of the contract game. In particular, firms search more intensely in price-first settings where they have relatively less bargaining power and their search angle is more biased in their own favor. Still, neither firm has incentives to search at the socially optimal level unless they obtain all the surplus generated from their efforts.

Figure 3 illustrates the regions in which firms search more or less in the price-first game relative to the price-last game, for any fixed search angle a and bargaining weight τ. The intuition for this figure can be seen by restricting attention to the region where $a \in (0, 0.25)$ and $\tau \in (0.5, 1)$; that is, the search angle is biased toward the seller and the bargaining power is biased toward the buyer. In this region, firm s searches more intensely in the price-first game, where no surplus is from their efforts is readjusted after the contract is determined. In contrast, firm b searches relatively more intensely in the price-last game when their search is biased toward their opponent, as their greater bargaining power allows them to redirect any new surplus toward themselves. The case where $a \in (-0.25, 0)$ and $\tau in (0, 0.5)$ is similarly, but with the incentives reversed. In the quadrants containing the thick black line, which represents the set of points at which each firm chooses the same search radius in both games, the "closer" of the two sub-regions determines the relative search intensity.

Figure 3: Relative search intensities for firms in price-first and price-last games



Notes: This figure represents results (ii) and (iii) of Proposition 1. Each search radius r_i is a function of firm i's own fixed search angle a_i. The blue and green areas represent the side of the 45-degree line of an angle. The vertically-hatched region corresponds to the area where b's search intensity is greatest in the price-last game, and s's search intensity is greatest in the price-first game; the opposite is depicted in the diagonally-hatched region.

To facilitate more detailed analysis, including comparative statics, we now add a functional form assumption for the firms' search cost functions.

A3 The investment cost function is $c_i(r_i, a_i) = 0.5\gamma_i r_i^2 \exp(-\gamma_a a_i^2)$ where γ_i is a firm-i specific cost parameter that is independent of the search angle a_i, and γ_a is common to both firms.

Note that under this assumption, there is no penalty for searching for the most mutually beneficial terms, i.e. those along the 45-degree line. While in general we may expect search for more welfare-enhancing terms to be more costly, this provides a useful benchmark for our analysis.

The preceding assumptions imply closed forms for firms' equilibrium search decisions for any given search angles. Note that under Lemma 1, the term-search maximization problems of firms b and s in the price-first setting are respectively

$$\max_{r_b} \quad r_b \cos(\theta(a_b)) + r_s \cos(\theta(a_s)) - 0.5\gamma_b r_b^2 \exp(-\gamma_a a_b^2)$$
$$\max_{r_s} \quad r_b \sin(\theta(a_b)) + r_s \sin(\theta(a_s)) - 0.5\gamma_s r_s^2 \exp(-\gamma_a a_s^2)$$

while for the price-last setting, the problems are

$$\max_{r_b} \quad \tau \cdot [r_b \cos(\theta(a_b)) + r_s \cos(\theta(a_s)) + r_b \sin(\theta(a_b)) + r_s \sin(\theta(a_s))] - 0.5\gamma_b r_b^2 \exp(-\gamma_a a_b^2)$$
$$\max_{r_s} \quad (1-\tau) \cdot [r_b \cos(\theta(a_b)) + r_s \cos(\theta(a_s)) + r_b \sin(\theta(a_b)) + r_s \sin(\theta(a_s))] - 0.5\gamma_s r_s^2 \exp(-\gamma_a a_s^2)$$

Evaluating the first-order conditions of the respective maximization problems yields the optimal search radii for any given search angles. These are summarized in Lemma 2.

Lemma 2. Let **A1**, **A2**, and **A3** hold. Then for any a_b and a_s, the optimal search radii are as follows in each case:

(i) the price-first game

$$r^*_{b,PF}(a_b) = \frac{1}{\gamma_b}\cos(\theta(a_b))\exp(\gamma_a a_b^2)$$
$$r^*_{s,PF}(a_s) = \frac{1}{\gamma_s}\sin(\theta(a_b))\exp(\gamma_a a_s^2)$$

(ii) the price-last game

$$r^*_{b,PL}(a_b) = \frac{\tau}{\gamma_b}[\cos(\theta(a_b)) + \sin(\theta(a_b))]\exp(\gamma_a a_b^2)$$
$$r^*_{s,PL}(a_s) = \frac{1-\tau}{\gamma_s}[\cos(\theta(a_s)) + \sin(\theta(a_s))]\exp(\gamma_a a_s^2)$$

(iii) the socially-optimal outcome

$$r^*_{b,opt}(a_b) = \frac{1}{\gamma_b}[\cos(\theta(a_b)) + \sin(\theta(a_s))]\exp(\gamma_a a_b^2)$$
$$r^*_{s,opt}(a_s) = \frac{1}{\gamma_s}[\cos(\theta(a_s)) + \sin(\theta(a_s))]\exp(\gamma_a a_s^2)$$

We note that investment in the price-first game does not depend on the bargaining weight, while each firm's investment is increasing in its own relative bargaining power in the price-last setting.

We next turn to a comparative statics analysis under three special cases. In the first two cases, each firm's search angle is exogenously assigned, reducing the search optimization problem of each firm to choosing one variable: search intensity r_i. In the first case we explore the comparative statics in the extreme case of orthogonal (self-interested) search. In the second case we explore the comparative statics in the opposite extreme of aligned search. In the third case, we assume the firms' search angles are endogenously determined, but bounded in absolute value by some exogenous constant $\bar{a} \leq 0.25$; we further consider the role of partial contractibility in contract development by varying this parameter.

4.2 Orthogonal (self-interested) search

We first consider the extreme case in which both firms search for terms that are value enhancing for themselves and value-neutral for the other firm. Using this assumption, we begin by solving for each firms search intensity in both the price first and price last model. In the first comparative statics analysis we assume search costs γ_i are the same for both firms. In the second comparative statics analysis we assume search costs are different. In both analyses we find that in the special case of orthogonal search, both firms strictly prefer the price-first game to the price-last game for all but the most extreme values of the bargaining weight τ.

In the context of our model, orthogonal search means we assume the firm search angles are $a_b = -0.25$ and $a_s = 0.25$ (that is, along the x- and y-axes in Figure 2). Since we assume search angles are exogenous for this special case, we also fix the angle cost parameter at $\gamma_a = 0$. By Lemma 1 and the functional form assumptions above, we know that the chosen term in game G has the associated expected payoff pair $v_b(m_{bs,G}) = r_{b,G}$ and $v_s(m_{bs,G}) = r_{s,G}$. This yields the following equilibrium investment in the price-first and price-last games.

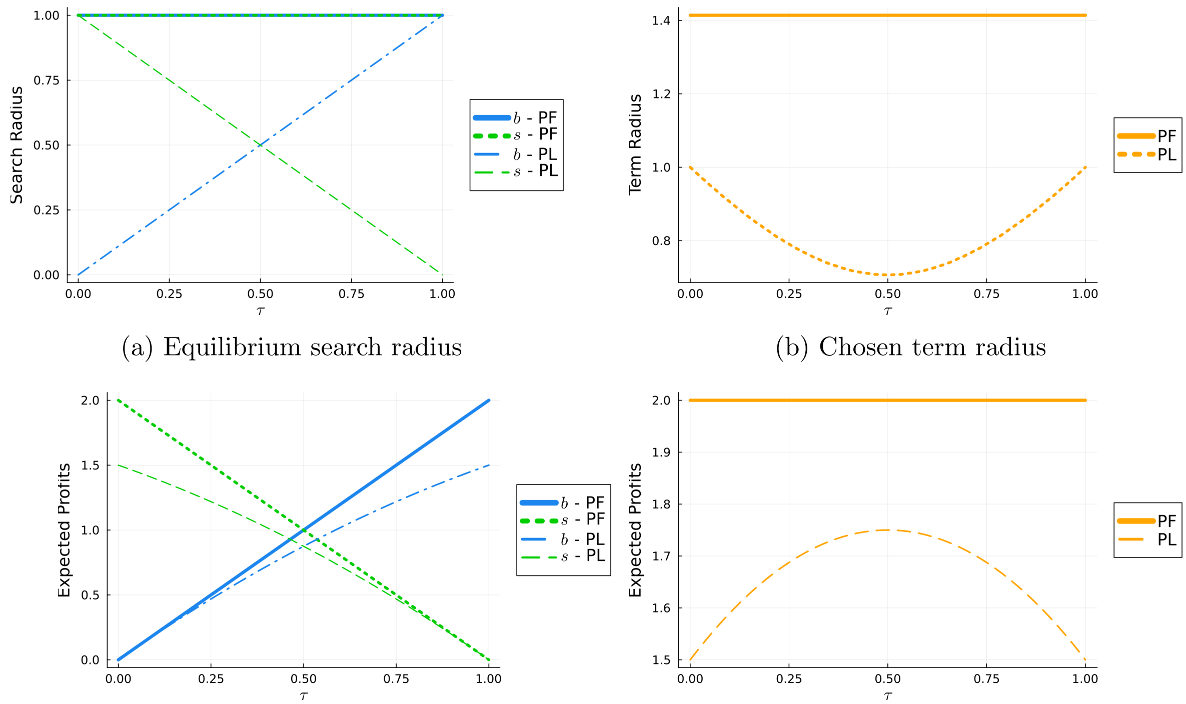
$$r^*_{b,PF} = \frac{1}{\gamma_b} \qquad\qquad r^*_{b,PL} = \frac{\tau}{\gamma_b}$$
$$r^*_{s,PF} = \frac{1}{\gamma_s} \qquad\qquad r^*_{s,PL} = \frac{1-\tau}{\gamma_s}$$

For all but extreme values of τ (i.e., $\tau = 0$ or $\tau = 1$), both firms under-invest in the price-last game relative to the price-first game. The socially optimal level of investment, given the fixed search angles, is obtained by both firms in the price-first game.

With $r^*_{i,PF}$ and $r^*_{i,PL}$ pinned down as a simple expression of exogenous parameters, we can now compare firm search intensity decisions and the corresponding firm payouts across the price first and price last models. We first compare outcomes when search costs γ_i are the same for both firms across the full range of values for the bargaining weight τ. We then compare outcomes when search costs are different for each firm by pinning down the search cost of the seller and then exploring how outcomes vary across a range of values for γ_b, the search cost of the buyer.

Figure 4 presents comparative statics for both games when setting search costs equal across firms and varying τ. The default parameter values are $\gamma_b = \gamma_s = 1$, $\gamma_a = 0$, $\pi_b = 2$, and $\pi_s = 1$. Panel (a) demonstrates how, except in the extreme case of either $\tau = 0$ or $\tau = 1$, firms in the price-first setting invest strictly more in developing new terms than in the price-last setting. As shown in panel (b), this yields more total search in the price-first game, particularly for intermediate levels of bargaining power. Regardless of the bargaining power held by each firm, panel (c) shows that both firms strictly prefer the price-first game to the price-last game for all $\tau \in (0, 1)$, yielding more total surplus (as indicated in panel (d)).

Figure 4: Comparative statics with respect to τ (orthogonal search)



(a) Equilibrium search radius

(b) Chosen term radius

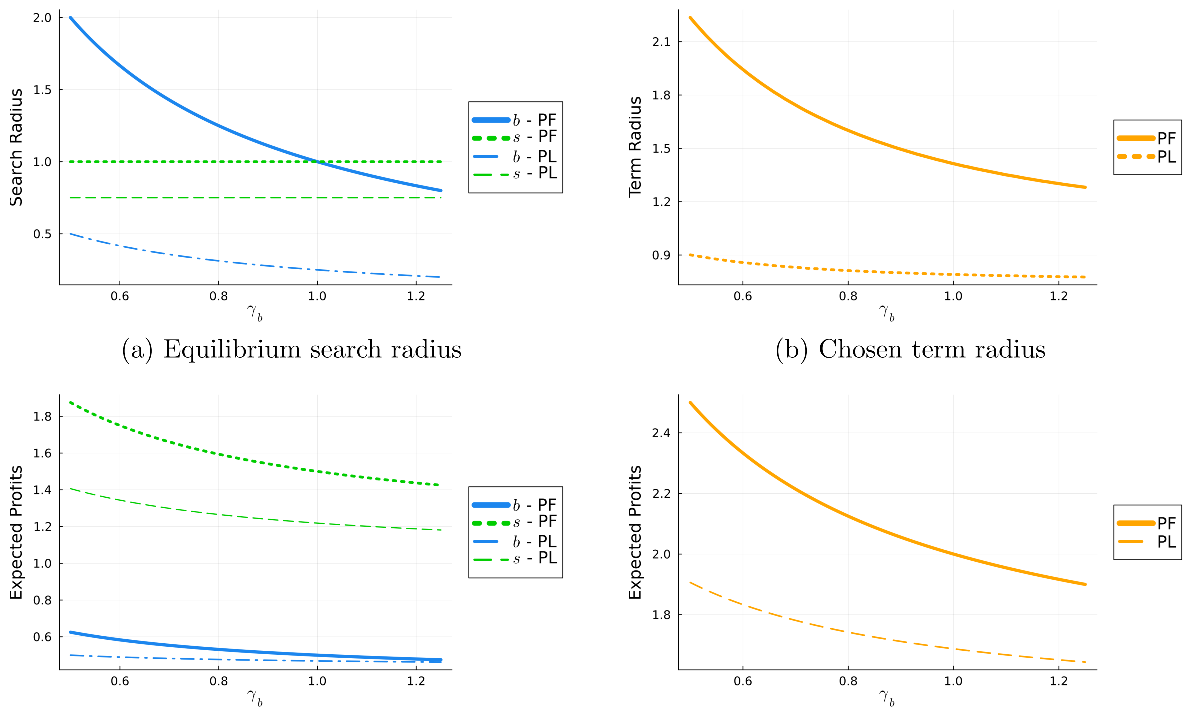
(c) Expected profits

(d) Expected combined profits

Notes: The panels on the left-hand side plot the variable of interest for both firms b and s in the price-first ("PF") and price-first ("PL") games. The panels on the right-hand side depict the corresponding outcomes of the contract in both games, for the combined firms. The plots assume $\gamma_b = \gamma_s = 1$, $\gamma_a = 0$, $\pi_b = 2$, and $\pi_s = 1$.

Figure 5 examines the case where firm b has low bargaining power ($\tau = 0.25$) but varying γ_b around the default seller cost parameter $\gamma_s = 1$. As before, we maintain $\pi_b = 2$ and $\pi_s = 1$. In both games, the two firms ultimately benefit from one party having lower search costs. As can be seen in panel (c), however, both firms gain more from a decrease in γ_b in the price-first game than the price-last game: firm b's investment response in the price-last game is muted by their inability to recover their whole investment in the price-last game. While the relative order of the contract terms and profits is preserved between the two games (as shown in Figure 4 for $\tau = 0.25$), we note that the contract terms and price are more sensitive to changes in γ_b in the price-first game relative to the price-last game.

Figure 5: Comparative statics with respect to γ_b (orthogonal search)



(a) Equilibrium search radius

(b) Chosen term radius

(c) Expected profits

(d) Expected combined profits

Notes: The panels on the left-hand side plot the variable of interest for both firms b and s in the price-first ("PF") and price-first ("PL") games. The panels on the right-hand side depict the corresponding outcomes of the contract in both games, for the combined firms. The plots assume $\tau = 0.25$, $\gamma_s = 1$, $\gamma_a = 0$, $\pi_b = 2$, and $\pi_s = 1$.

4.3 Aligned (surplus-maximizing) search

In contrast to the orthogonal search setting above, we now assume that firms' search angles are equal at $a_b = a_s = 0$ (i.e., the 45-degree line, which is the expected-surplus-maximizing angle for any fixed search radius). We again fix $\gamma_a = 0$ and consider the firms' search intensities and expected payoffs with both identical and heterogeneous search costs. Applying Lemma 1, we observe the expected payoffs in game G of $v_b(m_{bs,G}) = \sqrt{0.5}[r_{b,G} + r_{s,G}]$ and $v_s(m_{bs,G}) = \sqrt{0.5}[r_{b,G} + r_{s,G}]$.

From the equilibrium search intensities and the choice of search angles we see that firms choose the following search radii in the price-first and price-last games.

$$r^*_{b,PF} = \frac{\sqrt{0.5}}{\gamma_b} \qquad r^*_{b,PL} = \frac{\tau\sqrt{2}}{\gamma_b}$$

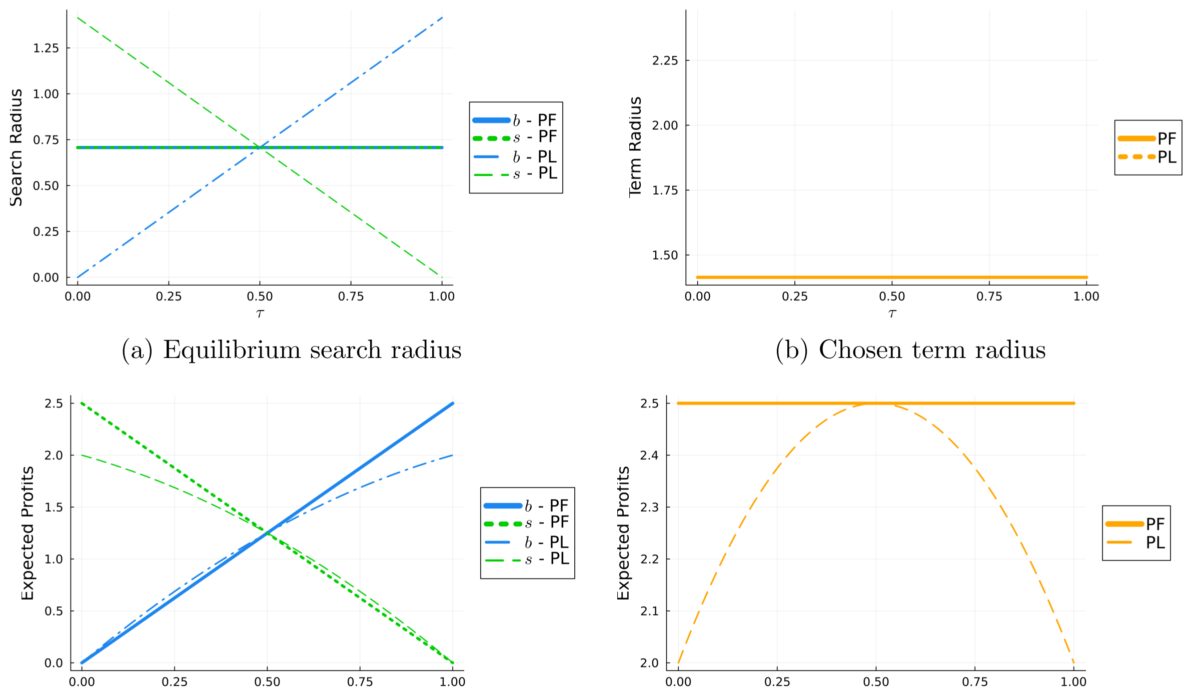
$$r^*_{s,PF} = \frac{\sqrt{0.5}}{\gamma_s} \qquad r^*_{s,PL} = \frac{(1-\tau)\sqrt{2}}{\gamma_s}$$

In this case, the firm with more (less) bargaining power will over- (under-) invest in search in the price-last model the relative to the price-first model; the two coincide for $\tau = 0.5$. As shown in

Proposition 1, the socially optimal level of investment is only attained in the price-last game when one firm has all the bargaining power.

Figure 6 presents comparative statics in the aligned search case when varying τ in both games. The default values are $\gamma_b = \gamma_s = 1$, $\gamma_a = 0$, $\pi_b = 2$, and $\pi_s = 1$. Panel (a) shows that the firm with more bargaining power will choose a larger search radius in the price-last game than in the price-first game, though as indicated by panel (b) the chosen term is in expectation identical in both games. Panels (c) and (d) in turn plot the individual and combined profits for both firms in both the price-first and price-last games. In contrast to the orthogonal search setting (where the price-first game strictly dominates the price-last game), the two firms are indifferent between the two games when $\tau = 0.5$. Further, the firm with less (but nonzero) bargaining power strictly prefers the price-last game to the price-first game.

Figure 6: Comparative statics with respect to τ (aligned search)



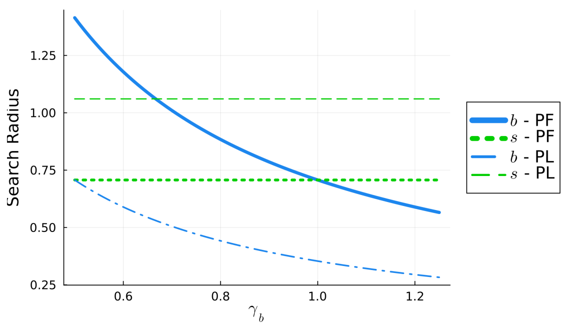
(a) Equilibrium search radius (b) Chosen term radius

(c) Expected profits (d) Expected combined profits

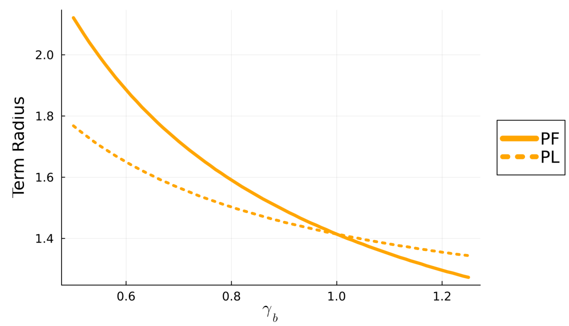
Notes: The panels on the left-hand side plot the variable of interest for both firms b and s in the price-first ("PF") and price-first ("PL") games. The panels on the right-hand side depict the corresponding outcomes of the contract in both games, for the combined firms. The plots assume $\gamma_b = \gamma_s = 1$, $\gamma_a = 5$, $\pi_b = 2$, and $\pi_s = 1$.

We again examine the role of heterogeneous search costs on equilibrium outcomes in the presence of asymmetric bargaining power. Figure 7 shows where firm b has low bargaining power ($\tau = 0.25$) and varying γ_b around the default seller cost parameter $\gamma_s = 1$. As before, we maintain $\pi_b = \pi_s = 0$. When compared to Figure 5(a), Figure 7 (a) shows that firm b's search response is more similar across games for a decrease in their search parameter γ_b. While all firms gain from the lower search costs in both games, the benefit is more drastic for firm b in the price-first game. In fact, for low enough search costs, firm b (the weaker bargainer) no longer prefers the price-last game; this differs from the symmetric-cost bargaining setting illustrated in Figure 6(c). Panel (b) shows that the price-first game yields more investment in new terms when the weaker bargainer is the stronger searcher, while overall innovation is less sensitive to changes in firm b's cost parameter in the price-last game. Since both firms search along the 45-degree line in this setting, the resulting contract terms always provide equal value to both parties.

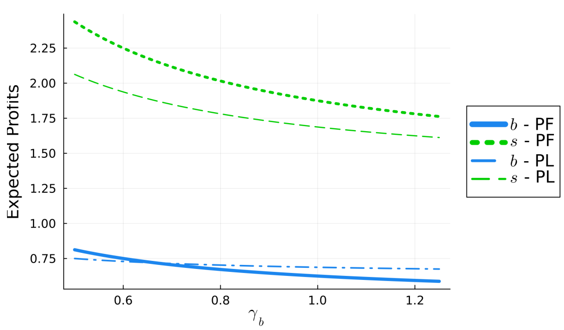
Figure 7: Comparative statics with respect to γ_b (aligned search)



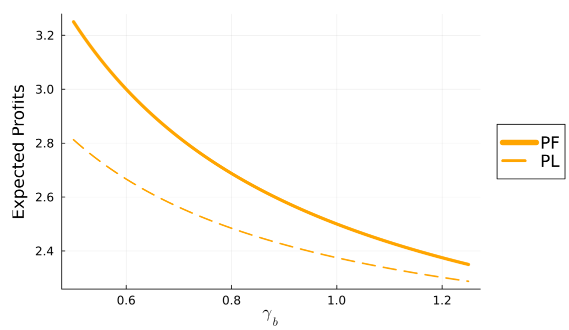
(a) Equilibrium search radius



(b) Chosen term radius



(c) Expected profits



(d) Expected combined profits

Notes: The panels on the left-hand side plot the variable of interest for both firms b and s in the price-first ("PF") and price-first ("PL") games. The panels on the right-hand side depict the corresponding outcomes of the contract in both games, for the combined firms. The plots assume $\tau = 0.25$, $\gamma_s = 1$, $\gamma_a = 5$, $\pi_b = 2$, and $\pi_s = 1$.

Collectively, these comparative statics analyses under both orthogonal and aligned search demonstrate that, when one accounts for the value of term innovation in the contracting process, setting price first is either weakly Pareto optimal or Kaldor Hicks optimal relative to setting price last across the full range of exogenous parameter values. This prediction, although consistent with industry practice in high stakes M&A deals, stands in stark contrast to the prediction in prevailing Nash bargaining models that predict welfare is maximized when parties barter over terms first and set price last.

4.4 Partially contractible term search

We now consider the case in which firms choose both their search intensity r^* and their search angle a_i^* subject to the constraint that $|a_i^*| \leq \bar{a}$. This case weakens the assumptions of the previous two cases, in which the angles are exogenous, but still restricts the angle of search to fall within some weak subset of the first quadrant. We assume this restriction arises from some combination of professional norms or the technology by which new terms are produced, ensuring that all terms must be at least weakly value-improving for both parties.

We begin by presenting a second proposition that follows from assumptions A1, A2, and A3 when we free up the search angle to be endogenous, though still constrained to fall within the first quadrant. To build intuition, we then consider two special cases of the value of the angle cost parameter: $\gamma_a = 0$ and $\gamma_a = 5$. Building on these special cases, we then present comparative statics for the full range of values for the bargaining weight τ and a wide range of values for γ_a. These comparative statics demonstrate that the price first game induces more aggressive term innovation relative to the price last game for all values of τ and γ_a and that the price first game is Pareto and/or Kaldor-Hicks dominant relative to the price last game for a wide range of the parameter space.

From the previous assumptions and Proposition 1, we obtain the unique optimal search radii as a function of the firms' search angles a_i. From the firms' optimal strategies for search intensity, we then solve for the optimal search angles under the constraint $|a_i| \leq \bar{a}$. We characterize this equilibrium in the following proposition.

Proposition 2. Let **A1**, **A2**, and **A3** hold. Then an equilibrium exists for both the price-first and price-last games when firms choose both the search radius r_i and the search angle a_i. Further

(i) in the price-first game, the unique optimal search angles are $a_{b,PF}^* = -\bar{a}$ and $a_{s,PF}^* = \bar{a}$.

(ii) in the price-last game for $\gamma_a \in [0, \pi^2]$, there is a unique optimal search angle $a_{i,PL}^* = 0$.

(iii) in the price-last game for $\gamma_a > \pi^2$, each firm has two optimal search angles that are unique up to their sign. These angles coincide with the constraint, i.e. $|a_{i,PL}^*| = \bar{a}$, for all $\gamma_a \geq \frac{\pi}{\bar{a}} \tan(\pi \bar{a})$.

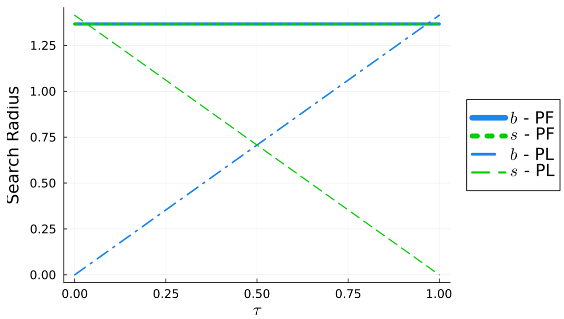
(Proof in Appendix A2)

The twin equilibrium search angles exist in the price-last game because all surplus is evenly split between both firms, so only the amount (and not the original allotments) of total surplus matters. In this case, both firms are equally compensated for their efforts when searching for terms that improve either their or their counterparts' payoffs. For clarity, and to facilitate comparisons with the previous two sections, we restrict attention to equilibria where $a_b \leq 0$ and $a_s \geq 0$ (that is, each firm searches on its own side of the 45-degree line).

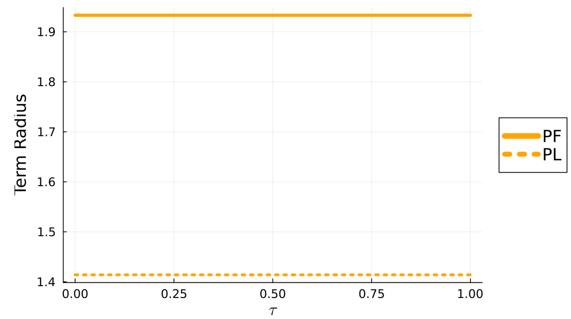
To fix ideas, we first examine the case where $\gamma_a = 0$ and $\bar{a} = 0.25$, i.e. when there is no penalty to searching along the 45-degree line and the entire first quadrant can be searched. In this case, the price-last game incentivizes the firms to search in the surplus-maximizing direction, since they will ultimately earn a share of the total surplus they generate. This coincides with the aligned search game considered above. In contrast, the price-first game incentivizes the firms to search in the most efficient direction to maximize their own payoff. Since the firms' search is limited only to the first quadrant, this coincides with the orthogonal search case. Evaluating firms' strategies and outcomes for various values of τ reveals that both the price-first and price-last games yield the same radius and angle for the resulting contract term, regardless of the value of τ. Further, both firms prefer the price-last game to the price-first game for any $\tau \in (0, 1)$ (see Figure A3.1 in the appendix for more details).

To compare firms' search decisions and outcomes in this more relaxed setting, we now present several comparative statics with respect to the key parameter values in this model: the bargaining weight τ and the angle-specific cost parameter γ_a. Figure 8 illustrates the case where $\gamma_a = 5$ and $\bar{a} = 0.25$. Panel (a) shows that, with the exception of the stronger bargaining firm for extreme values of τ, the price-first game incentivizes larger firm search radii than the price-last game; these imply the equilibrium radius of the chosen term is larger in the price-first game than the price-last game (see panel (b)). Panels (c) and (d) together illustrate how the higher cost to searching along the 45-degree line yields higher surplus in settings where one firm is a particularly stronger bargainer. This holds even when the cost parameter γ_a is not sufficiently large to deter firms from searching in the surplus-maximizing direction in the price-last game.

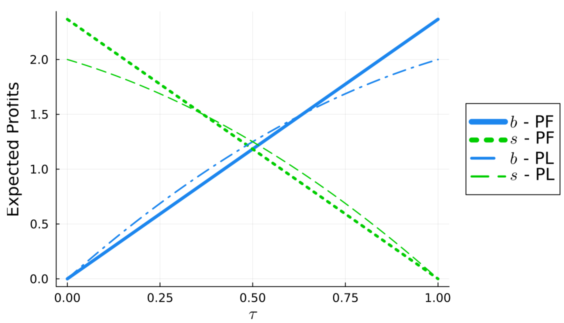
Figure 8: Comparative statics with respect to τ (endogenous angle search)



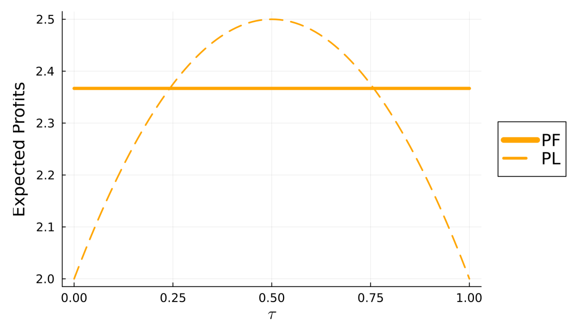
(a) Equilibrium search radius



(b) Chosen term radius



(c) Expected profits

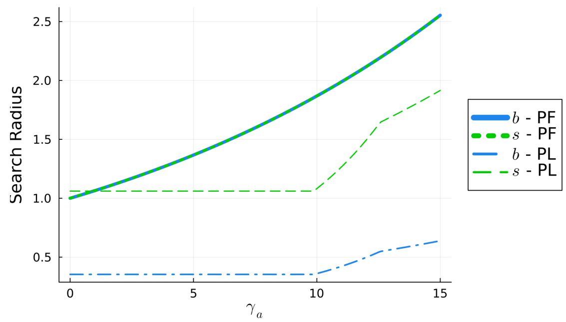


(d) Expected combined profits

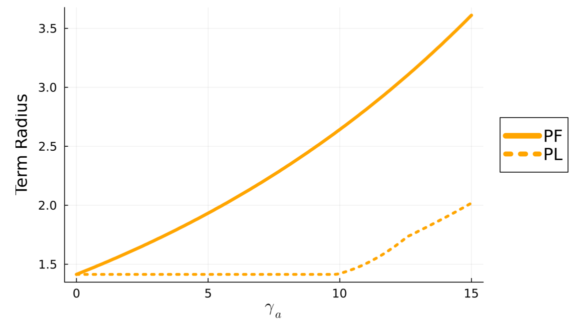
Notes: The panels on the left-hand side plot the variable of interest for both firms b and s in the price-first ("PF") and price-first ("PL") games. The panels on the right-hand side depict the corresponding outcomes of the contract in both games, for the combined firms. The plots assume $\gamma_b = \gamma_s = 1$, $\gamma_a = 5$, $\bar{a} = 0.25$, $\pi_b = 2$, and $\pi_s = 1$.

We now examine comparative statics with respect to γ_a in Figure 9. For these figures, we set $\tau = 0.25$ and $\gamma_b = \gamma_s = 1$. As shown in panel (a), increasing γ_a makes searching near the axes (i.e., for high $|a_i|$) cheaper, incentivizing both firms to increase their search radii whenever $a_i \neq 0$. Firms' additional efforts in increasing the search radius implies strictly more innovation in the chosen contract term in the price-first game relative to the price-last game, as shown in panel (b). Panel (c) plots the equilibrium search angles as indicated by Proposition 2, with the additional restriction that $a_b \leq 0$ and $a_s \geq 0$. When the cost of searching for surplus-maximizing (i.e., low $|a_i|$) terms is sufficiently high, the price-last game will be biased toward the firm with more bargaining power (panel (d)). Together, this implies that sufficiently high γ_a implies the price-first game generates more total surplus (see panel (f)). In fact, panel (e) indicates that the price-first game may even be strictly preferred by both firms for high enough values of γ_a.

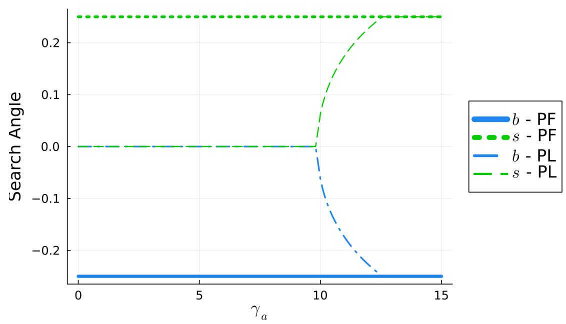
Figure 9: Comparative statics with respect to γ_a (endogenous angle search)



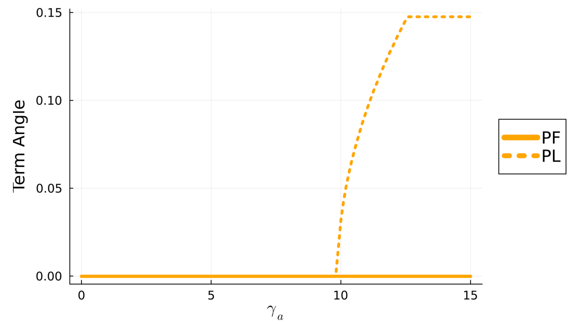
(a) Equilibrium search radius



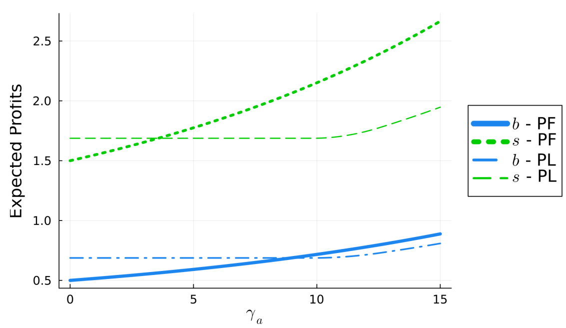
(b) Chosen term radius



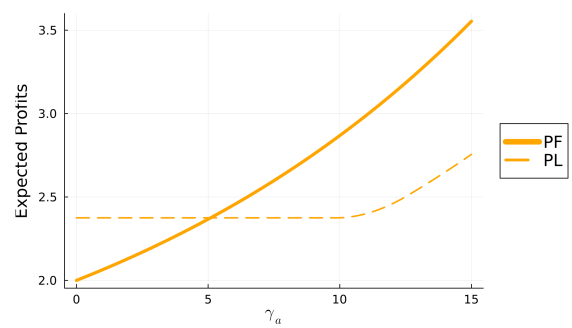
(c) Equilibrium search angle



(d) Chosen term angle



(e) Expected profits



(f) Expected combined profits

Notes: The panels on the left-hand side plot the variable of interest for both firms b and s in the price-first ("PF") and price-first ("PL") games. The panels on the right-hand side depict the corresponding outcomes of the contract in both games, for the combined firms. The plots assume $\tau = 0.25$, $\gamma_b = \gamma_s = 1$, $\pi_b = 2$, and $\pi_s = 1$.

4.5 Equilibrium contract under alternative assumptions

We now briefly examine another specification of the model, which allows for endogenous search angles and radius under various alternative assumptions. Unlike in the previous section, firms can now search for any type of contract term—even those that may be actively harmful to their counterpart. We also allow for term-specific productivity shocks to vary across terms, implying that any individual firm's proposed contract term may be preferred to the combined contract term in a specific setting. Thus, firms have full flexibility in using their search decisions to determine the expected payoff from their proposed term, as well as the probability it is selected. The central question is now how timing affects the contract creation process in the absence of any restrictions on firms' search process.

In order to understand this question, we continue to make some simplifying assumptions for tractability. Instead of assuming the shocks ϵ_j are perfectly correlated, we instead assume they are independent and make a functional form assumption that yields closed-form choice probabilities. This means there is an option value to variety even if the terms have the same expected value for both parties. Thus, firms' investment decisions are shaped by the knowledge that their own term may be chosen instead of the combined term, since the combined term may be ill-suited for a deal relative to either of the simpler individual contract terms.

Modifying these assumptions shows how firms' incentives differ when their individual terms may be chosen. Since productivity shocks are independent, and firms have a nonzero chance of only their term being chosen in the bartering process, they offer more neutral terms (lower $|a_i|$) in the price-first game, and they increase their search radii when they have more bargaining power. Firms behave similarly in the price-last game as under the previous assumptions, generally searching in the surplus-maximizing direction because all surplus will be redistributed later and a larger "pie" is beneficial. We study this setting in detail now.

4.5.i Alternative assumptions and implications for the expected contract

We replace assumptions **A1** and **A2** with the following two assumptions:

- **B1** The direction of search may be any angle within the entire unit circle, i.e. $|a_i| \leq 1.0$.
- **B2** ϵ_j is i.i.d. Frechet (inverse Weibull) with shape parameter $\alpha > 1$ and scale parameter $\sigma = \Gamma(1 - 1/\alpha)^{-1}$, implying $\mathbb{E}[\epsilon_j] = 1$ for all j.

The first assumption expands the set of possible contract terms to include those that may be value-destroying for one of the two parties.[15] The second assumption helps achieve tractability by yielding functional forms for conditional choice probabilities and conditional expected values, as in Eaton and Kortum (2002) and more broadly in the empirical discrete choice literature (see e.g. Berry and Haile 2021).[16]

Assumption **B2** implies several closed forms for important quantities in both the price first and price last game. Recall that in the bartering for terms stage of game G, firms choose whichever

15. These bounds are only imposed to avoid coterminal angles, i.e. those that differ by some multiple of 2π.

16. Importantly, $\epsilon_{bs} \perp\!\!\!\perp \epsilon_b$, ϵ_s. While this is a strong assumption, it will be helpful in both theoretical and empirical applications; such benefits will be highlighted below. More complex correlation structures may also be helpful; see e.g. the nested Frechet model in Lashkaripour and Lugovskyy 2023 as well as the larger literature using variations of the nested logit model for demand estimation. We use the extreme case of full independence in contrast with the other extreme, perfect correlation, which we consider above.

term of $\mathcal{M}^* = \{m_s^*, m_b^*, m_{bs}^*\}$ yields the greatest Nash product:

$$m_G^* = \underset{m_j \in \mathcal{M}^*}{\text{argmax}} \quad NP_{j,G}$$

where $NP_{j,PF} = \delta_{j,PF} \cdot \epsilon_j$ and $\delta_{j,PF} = v_b(m_j)^\tau \cdot v_s(m_j)^{1-\tau}$, while $NP_{j,PL} = \delta_{j,PL} \cdot \epsilon_j$ and $\delta_{j,PL} = v_b(m_j) + v_s(m_j)$. [17]

Then the equilibrium choice probability for any term j is

$$\lambda_{j,G}^* \equiv \mathbb{P}[j \text{ is chosen in game } G] = \frac{(\delta_{j,G}^*)^\alpha}{\sum_k (\delta_{k,G}^*)^\alpha}$$

Thus, any term that offers strictly positive surplus to both firms in the price-first game has a strictly positive probability of being selected through Nash bartering. Using the expectation of the maximum of Frechet random variables,[18] we have

$$\mathbb{E}[\epsilon_{j,G}^*] = \frac{1}{\delta_{j,G}^*} \cdot \Big(\sum_k (\delta_{k,G}^*)^\alpha\Big)^{1/\alpha} = (\lambda_{j,G}^*)^{-1/\alpha}$$

This expression illustrates the option value of choosing between multiple contracts - even though all ϵ_j have mean 1, conditioning on that term being chosen means the Nash product (and the associated payoffs) will be higher on average than the unconditional average payoffs. Finally, by the law of total expectation, the expected value of firm payoffs from the term stage, $U_{i,G}$, is written as

$$U_{i,G}^* = \sum_{j \in \mathcal{M}} v_i(m_{j,G}^*) \cdot (\lambda_{j,G}^*)^{1-1/\alpha}$$

That is, the expected value from each individual contract is weighted by the probability it is chosen and its expected value conditional on being chosen in game G.

4.5.ii Comparative statics

Figure 10 plots the outcomes for the contracting process for different values of the bargaining weight τ. In this case we see that both games induce greater search efforts by the stronger bargainer, as represented by the larger search radius. Note that relative to the game in Figure 8, the search angles in the price-first game are shifted toward the center, particularly for the firm with less bargaining power. This is because the bartering process rewards terms that offer a higher Nash product, particularly by placing non-zero probability on choosing any individual term proposed by a single firm. However, the firms in the price-last game still search at $a_i = 0$ since it is surplus-

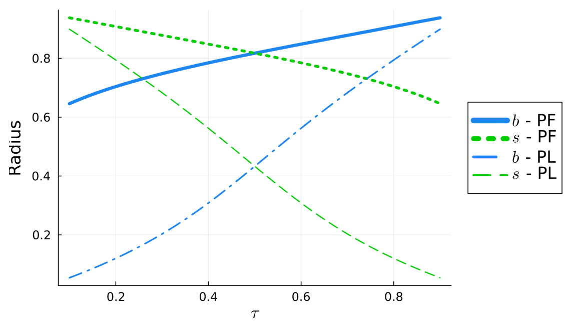
17. For ease of reference, recall these derivations are found in Subsection 3.2 (price-first) and Subsection 3.3 (price-last).

18. In particular, $\mathbb{E}[\epsilon_{j,G}^*] = \frac{1}{\delta_{j,G}}\mathbb{E}[NP_{j,G} \mid j \text{ is chosen in } G]$ and under **B2** it holds that $\mathbb{E}[NP_{j,G} \mid j \text{ is chosen in } G] = (\sum_k (\delta_{k,G}^*)^\alpha)^{1/\alpha}$.

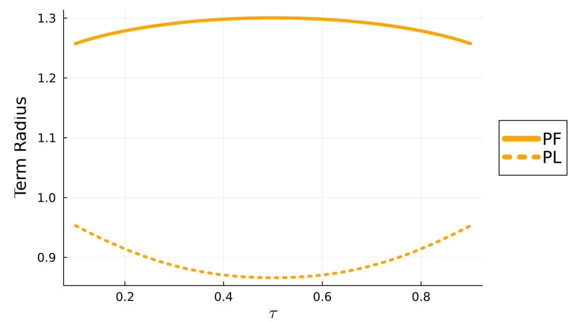
maximizing.

As with the endogenous search angle game in 4.4, the stronger bargainer generally prefers the price-last game. However, the combination of the firms' angle and radius choices in this setting imply that the expected joint profits are nearly equal across the two games (with the price-first game generating slightly higher surplus). This results in greater investment in the joint term in the price-first game than for the price-last game, particularly for intermediate values of τ, and a term angle that is biased toward the stronger bargainer in the price-first game.

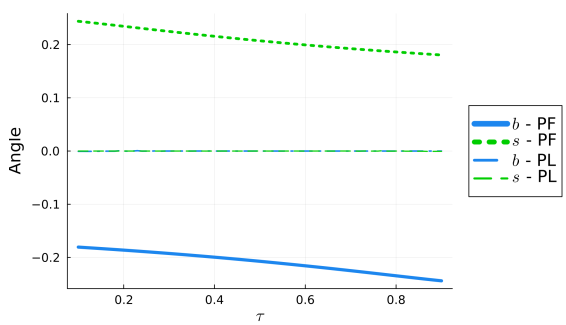
Figure 10: Comparative statics with respect to τ (unrestricted term search)



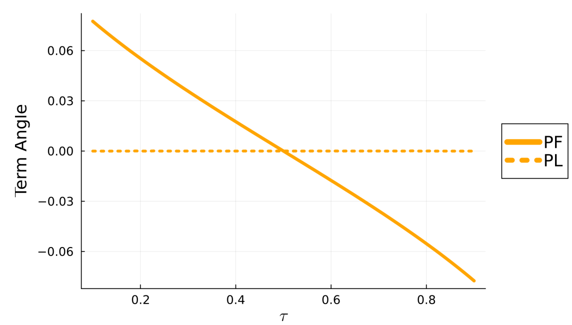
(a) Equilibrium search radius



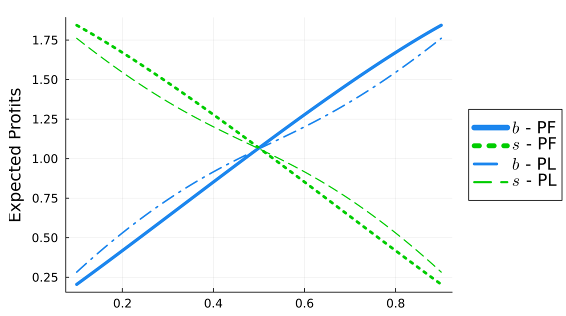
(b) Chosen term radius



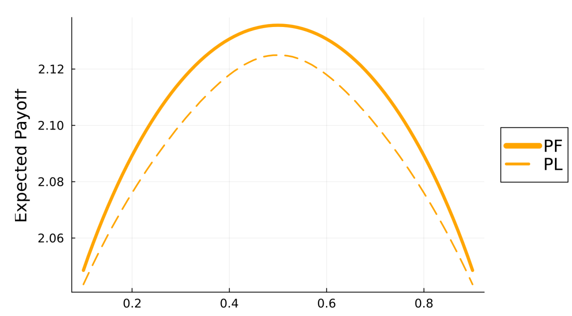
(c) Equilibrium search angle



(d) Chosen term angle



(e) Expected profits



(f) Expected combined profits

Notes: The panels on the left-hand side plot the variable of interest for both firms b and s in the price-first ("PF") and price-first ("PL") games. The panels on the right-hand side depict the corresponding outcomes of the contract in both games, for the combined firms. The plots assume $\alpha = 2$, $\gamma_b = \gamma_s = 1$, $\gamma_a = 5$, $\pi_b = 2$, and $\pi_s = 1$.

5 Conclusion

In this article, we have presented an analytic framework that combines a bargaining model and a search game over innovative contractual provisions to reconcile a longstanding puzzle in contract design: the counterintuitive practice in complex markets of setting price terms before negotiating non-price terms. Our framework delivers a robust and tractable set of intuitions about when fixing price before other terms optimally incentivizes strategic search investments by the contracting parties.

We hope that this model provides a launchpad for further efforts. By modeling firms' investment decisions in the contract construction process, we allow for extensions to the case where firms can exit the negotiation process after discovering new terms. Given the empirical tractability of our model, this enables researchers to evaluate the impact of reliance and expectation measures of damages. More broadly, this model can be used to more accurately estimate the value of contract terms in real-world contracts even in the absence of explicit price renegotiation.

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A1 Stochastic Nash bartering

Traditional Nash bargaining assumes a convex choice set, though other work weakens this assumption (Herrero 1989; Zhou 1997; Serrano and Shimomura 1998). In our setting, we have a discrete set of possible terms that can be chosen. We wish to represent the term bartering game as an instant decision that relies on firm bargaining power in the same way as prices are set via Nash bargaining. We illustrate how the stochastic Nash bargaining solution is in expectation equal to the classic Nash bargaining solution over the convex hull of *ex ante* expected payoffs from possible choices of contract terms.

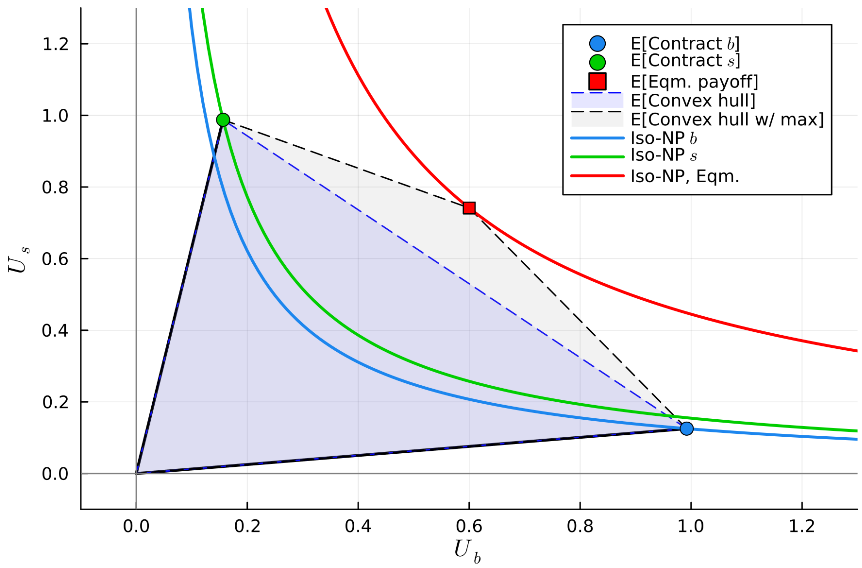
The stochastic Nash bartering solution we propose also coincides with the Nash bargaining solution on an *ex ante* convexification of the expected payoff set. We define the expected payoff set $PS_E = \{\mathbb{E}[v(m_j;\epsilon_j)] \mid m_j \in \mathcal{M}\} \cup \{\mathbb{E}[v(m_j;\epsilon_j) \mid NP_j \geq NP_k \ \forall k \neq j]\}$. That is, PS_E is the set of achievable expected payoffs from any individual term and the expected payoff from selecting the term with the highest realized Nash product (under whichever game is being considered). Let PS_∞ be the convex hull of the expected payoff set PS_E. Consider any randomization protocol on PS_E, so any feasible payoff in the convex hull PS_∞ can be represented by the lottery on PS_E. Then the solution of the Nash bargaining program over the convex set PS_∞ is equal to the solution of choosing $\mathbb{E}[v(m_j;\epsilon_j) \mid NP_j \geq NP_k \ \forall k \neq j]$ from the restricted set PS_E.[19] The difference $\mathbb{E}[v(m_j;\epsilon_j) \mid NP_j \geq NP_k \ \forall k \neq j] - \max_{m_j \in \mathcal{M}}\{\mathbb{E}[v(m_j;\epsilon_j)]\}$ is strictly positive when there are at least two non-default terms in $\mathcal{M}$, and it represents the expected option value from having multiple potential contracts to choose from.

Figure A1.1 illustrates the expected convex hull PS_∞ of the set of expected payoffs PS_E, represented by the grey and blue shaded areas. The blue shaded area represents the convex hull only over the proposed contracts m_0, m_b, and m_s (i.e., $PS_E \setminus \{\mathbb{E}[v(m_j;\epsilon_j) \mid NP_j \geq NP_k \ \forall k \neq j]\}$). If the firms commit *ex ante* to select the term with highest Nash product once all uncertainty is resolved, the expected payoff exceeds that of any other contract selection rules in the convex hull.

19. In other words, any distinct randomization protocol over the terms in the set PS_E (that places positive probability on any term in $\mathcal{M}$, regardless of the realization of ϵ) will in expectation do worse (in the Nash program sense) than choosing whichever term has the highest Nash product after ϵ is drawn.

In the simple case where there are only 2 terms other than the default term (and terms cannot be added together), the expected payoff is also a weighted average of the expected payoffs from each term conditional on that term being selected; see Figure A4.1(a) for an illustration.

Figure A1.1: Firm payoffs in the bartering stage of the price-first game (unrestricted model)



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Notes: The plots assume $r_b = 1$, $r_s = 1.25$, $a_b = -0.19$, $a_s = 0.22$, $\alpha = 4$, and $\tau = 0.4$. None of these values necessarily represent equilibrium actions. For clarity in illustrating the expected convex hull, we present a modified case where the combined term is not considered by the firms.

A2 Proofs and derivations

Proof of Proposition 1

The first-order conditions for b and s in PF and PL are

$$
\begin{aligned}
&\{b, PF\} && \frac{\partial}{\partial r_b} c_b(r_b, a_b) = \cos(\theta(a_b)) \\
&\{s, PF\} && \frac{\partial}{\partial r_s} c_s(r_s, a_s) = \sin(\theta(a_s)) \\
&\{b, PL\} && \frac{\partial}{\partial r_b} c_b(r_b, a_b) = \tau[\cos(\theta(a_b)) + \sin(\theta(a_b))] \\
&\{s, PL\} && \frac{\partial}{\partial r_s} c_s(r_s, a_s) = (1-\tau)[\cos(\theta(a_s)) + \sin(\theta(a_s))]
\end{aligned}
$$

For fixed angles a_i in the first quadrant and fixed bargaining parameter $\tau \in [0, 1]$, each of the right-hand side expressions are weakly positive constants, while the left-hand side expressions are increasing in r. Since $c_i(\cdot, a_i) = 0$ and $\frac{\partial c_i(r_i, a_i)}{\partial r_i}|_{r_i=0} = 0$, this is the unique value that satisfies the first-order conditions. Further, since the right-hand sides of the above expressions do not depend on r_i and costs are convex in r_i, the second-order conditions hold. Thus, the equilibrium exists and is unique for both the price-first and price-last games.

Further note that since c_i is increasing in the search radius r_i and search angles a_i are fixed across the two games, search intensity is higher in whichever game results in higher investment costs. For firms b and s respectively, this implies that search intensity is higher when

$$\begin{aligned}
&\{b\} && \cos(\theta(a_b)) \geq \tau[\cos(\theta(a_b)) + \sin(\theta(a_b))] \\
&\{s\} && \sin(\theta(a_s)) \geq \tau[\cos(\theta(a_s)) + \sin(\theta(a_s))]
\end{aligned}$$

or equivalently,

$$\begin{aligned}
&\{b\} && a_b \leq \frac{1}{\pi}\arctan\left(\frac{1-\tau}{\tau}\right) - 0.25 \\
&\{s\} && a_s \geq \frac{1}{\pi}\arctan\left(\frac{1-\tau}{\tau}\right) - 0.25
\end{aligned}$$

Note that the socially optimal level of investment maximizes the total surplus from producing new terms, net of search costs. That is, a social planner solves

$$\max_{r_b, r_s} \quad [r_b \cos(\theta(a_b)) + r_b \sin(\theta(a_b)) + r_s \cos(\theta(a_s)) + r_s \sin(\theta(a_s))] - c_b(r_b, a_b) - c_s(r_s, a_s)$$

Taking first-order conditions yields

$$\begin{aligned}
\frac{\partial}{\partial r_b} c_b(r_b, a_b) &= \cos(\theta(a_b)) + \sin(\theta(a_b)) \\
\frac{\partial}{\partial r_s} c_s(r_s, a_s) &= \sin(\theta(a_s)) + \cos(\theta(a_s))
\end{aligned}$$

The right-hand sides weakly exceed the corresponding right-hand side expressions for the first-order conditions of both firms in the both the price-first and price-last games. Since costs are convex, this implies the socially optimal level of investment is weakly higher than the investment by either firm in either game. This inequality is strict except where $\tau \in \{0, 1\}$ in the price-last game (in which case exactly one of the two firms invests at the socially optimal level) and where $|a_i| = 0.25$ in the price-first game (in which case both firms invest at the socially optimal level).

Proof of Proposition 2

Lemma 1 provides the optimal search radii in each game as functions of the search angle. Plugging in these strategies yields the following maximization problems in the price-first setting

$$\begin{aligned}
\max_{a_b\colon |a_b| \leq \bar{a}} \quad & \left[\frac{1}{\gamma_b}\cos(\theta(a_b))^2 \exp(\gamma_a a_b^2) + \frac{1}{\gamma_s}\cos(\theta(a_s))\sin(\theta(a_s))\exp(\gamma_a a_s^2)\right] \\
& - 0.5\frac{1}{\gamma_b}\cos(\theta(a_b))^2 \exp(\gamma_a a_b^2) \\
\max_{a_s\colon |a_s| \leq \bar{a}} \quad & \left[\frac{1}{\gamma_b}\cos(\theta(a_b))\sin(\theta(a_b))\exp(\gamma_a a_b^2) + \frac{1}{\gamma_s}\sin(\theta(a_s))^2 \exp(\gamma_a a_s^2)\right] \\
& - 0.5\frac{1}{\gamma_s}\sin(\theta(a_s))^2 \exp(\gamma_a a_s^2)
\end{aligned}$$

and the price last setting

$$
\begin{aligned}
\max_{a_b:\,|a_b|\leq\bar{a}} \quad & \tau \cdot \left[\frac{\tau}{\gamma_b}(1+\sin(2\theta(a_b)))\exp(\gamma_a a_b^2) + \frac{1-\tau}{\gamma_s}(1+\sin(2\theta(a_s)))\exp(\gamma_a a_s^2)\right] \\
& - 0.5\frac{\tau^2}{\gamma_b}[1+\sin(2\theta(a_b))]\exp(\gamma_a a_b^2) \\
\max_{a_s:\,|a_s|\leq\bar{a}} \quad & (1-\tau)\cdot \left[\frac{\tau}{\gamma_b}(1+\sin(2\theta(a_b)))\exp(\gamma_a a_b^2) + \frac{1-\tau}{\gamma_s}(1+\sin(2\theta(a_s)))\exp(\gamma_a a_s^2)\right] \\
& - 0.5\frac{(1-\tau)^2}{\gamma_s}[1+\sin(2\theta(a_s))]\exp(\gamma_a a_s^2)
\end{aligned}
$$

Proof of (i). We now focus on the price-first setting. First define $f_{i,PF}(a_1)$ for $i \in \{b, s\}$ as firm i's expected payoff when choosing angle a minus their expected payoff from choosing $-a$, for any fixed angle from firm i's counterpart $-i$. That is,

$$
\begin{aligned}
f_{b,PF}(a) &= \frac{1}{2\gamma_b}\exp(\gamma_a a_1^2)\left[\cos(\theta(a))^2 - \cos(\theta(-a))^2\right] \\
f_{s,PF}(a) &= \frac{1}{2\gamma_s}\exp(\gamma_a a_2^2)\left[\sin(\theta(a))^2 - \sin(\theta(-a))^2\right]
\end{aligned}
$$

For $a > 0$, we have $f_{b,PF}(a) < 0$ ($-a$ dominates a) and $f_{s,PF}(a) > 0$ (a dominates $-a$). Thus b always chooses $a^*_{b,PF} \in [-\bar{a}, 0]$ (the "lower half" of the first quadrant) and s always chooses $a^*_{s,PF} \in [0, \bar{a}]$ (the "upper half" of the first quadrant).

Taking derivatives of the firms' profit functions with respect to their choice variables yields the following expressions

$$
\begin{aligned}
\{b\} \qquad & \frac{1}{\gamma_b}\exp(\gamma_a a_b^2)\cdot\cos(\theta(a_b))\cdot\Big[\gamma_a a_b\cos(\theta(a_b)) - \pi\sin(\theta(a_b))\Big] \\
\{s\} \qquad & \frac{1}{\gamma_s}\exp(\gamma_a a_s^2)\cdot\sin(\theta(a_s))\cdot\Big[\gamma_a a_s\sin(\theta(a_s)) + \pi\cos(\theta(a_s))\Big]
\end{aligned}
$$

For $|a| \leq 0.25$ (i.e., a within the first quadrant), $\cos(\theta(a))$ and $\sin(\theta(a))$ at least weakly positive, which implies that the terms preceding the brackets are positive. Note that $sign(\gamma_a a_b \cos(\theta(a_b))) = sign(\gamma_a a_s \sin(\theta(a_s))) = sign(a_s)$ for a_b, a_s within the first quadrant. This implies that the derivative for firm b is weakly negative when $a_b \in [-\bar{a}, 0]$ and the derivative for firm s is weakly positive for $a_s \in [0, \bar{a}]$ (these are strict for either $\gamma_a > 0$ or $|a_i| \neq 0.25$). Therefore, for all $\gamma_a \geq 0$, it holds that the unique optimal search angles in the price-first game are $a^*_{b,PF} = -\bar{a}$ and $a^*_{s,PF} = \bar{a}$.

Proof of (ii). We now turn to the price-last setting. We have the following derivatives of the firms' maximization problems with respect to their own search angles, after applying trigonometric identities:

$$\{b\} \qquad \frac{1}{\gamma_b}\exp(\gamma_a a_b^2)\cdot\tau^2\cdot 2\pi\cos(\pi a_b)\Big[\frac{\gamma_a}{\pi}a_b\cos(\pi a_b)-\sin(\pi a_b)\Big]$$
$$\{s\} \qquad \frac{1}{\gamma_s}\exp(\gamma_a a_s^2)\cdot(1-\tau)^2\cdot 2\pi\cos(\pi a_s)\Big[\frac{\gamma_a}{\pi}a_s\cos(\pi a_s)-\sin(\pi a_s)\Big]$$

The terms preceding the brackets are weakly positive for all angles within the first quadrant (strictly so for $\tau \in (0,1)$). Therefore, the signs and zeros of these derivatives are determined solely by the signs and zeros of the bracketed terms. We now restrict attention to only the bracketed terms, which have the same functional form for both firms.

Denote $f_1(a) = \frac{a}{\pi}\cos(\pi a)$ and $f_2(a) = \sin(\pi a)$, and define $f(a,\gamma_a) \equiv \gamma_a f_1(a) + f_2(a)$. Since $f(0,\gamma_a) = 0$, the angle $a_i = 0$ always satisfies the interior first-order condition. Differentiating $f(a,\gamma_a)$ with respect to a, we have

$$\frac{1}{\pi}[\gamma_a - \pi^2]\cos(\pi a) - \gamma_a a\sin(\pi a)$$

Note that for $|a| \leq 0.25$, it holds that $\cos(\pi a) > 0$ and $a\sin(\pi a) \geq 0$ (with strict inequality for $a \neq 0$). Assume that $\gamma_a < \pi^2$, which implies that $\frac{\partial}{\partial a} f(a,\gamma_a) < 0$ for $|a| \leq \bar{a}$. Since $f(0,\gamma_a) = 0$, monotonicity of f in a implies

$$f(a,\gamma_a)\begin{cases} > 0 & \text{if } a \in [-\bar{a}, 0) \\ < 0 & \text{if } a \in (0, \bar{a}] \end{cases}$$

That is, firms' profits are increasing in a for $a < 0$ and decreasing in a for $a > 0$. This implies that the unique optimal choice of a is $a^* = 0$ for $|a| \leq 0.25$ for $\gamma_a < \pi^2$.

Proof of (iii). We now consider the case where $\gamma_a > \pi^2$. Denoting $g_{i,PL}(a,\gamma_a)$ as the derivative of firm i's maximization problem with respect to its own choice angle, note that $g_{i,PL}(a,\gamma_a) = -g_{i,PL}(-a,\gamma_a)$, implying $g'_{i,PL}(a,\gamma_a) = g'_{i,PL}(-a,\gamma_a)$. Thus, for any angle a that is optimally chosen by firm i, the angle $-a$ also satisfies both the first- and second-order conditions. We therefore restrict attention (without loss of generality) to $a \in [0,\bar{a}]$.

We first consider $a = 0$. Note that $f(0,\gamma_a) = 0$ and $\frac{\partial f(a,\gamma_a)}{a}|_{a=0} > 0$, implying by the product rule that the second derivative of firms' maximization problem is positive at $a = 0$. Thus, $a = 0$ is not optimal when $\gamma_a > \pi^2$.

We now consider $a \in (0,\bar{a}]$, and look for solutions of the first-order condition. Dividing the equation $f(a,\gamma_a) = 0$ on both sides by $\frac{a}{\pi}\cos(\pi a)$ (which is strictly positive for $0 < |a| \leq 0.25$) yields

$$0 = \gamma_a - \frac{\pi}{a}\tan(\pi a)$$

We examine the second term, $\frac{\pi}{a}\tan(\pi a)$, to determine the behavior of this transformed first-order condition as a varies. Note that at the lower limit of this interval, we have

$$\lim_{a\downarrow 0}\frac{\pi}{a}\tan(\pi a)=\lim_{a\downarrow 0}\pi^2\sec^2(\pi a)=\pi^2$$

We examine how this function varies with a for $a>0$. By applying trigonometric identities, we obtain

$$\begin{aligned}\frac{\partial}{\partial a}\left(\frac{\pi}{a}\tan(\pi a)\right)&=\frac{\pi}{a^2}\Bigg[\pi a\sec^2(\pi a)-\tan(\pi a)\Bigg]\\&=\frac{\pi}{a^2\cos^2(\pi a)}\Bigg[\pi a-0.5\sin(2\pi a)\Bigg]\end{aligned}$$

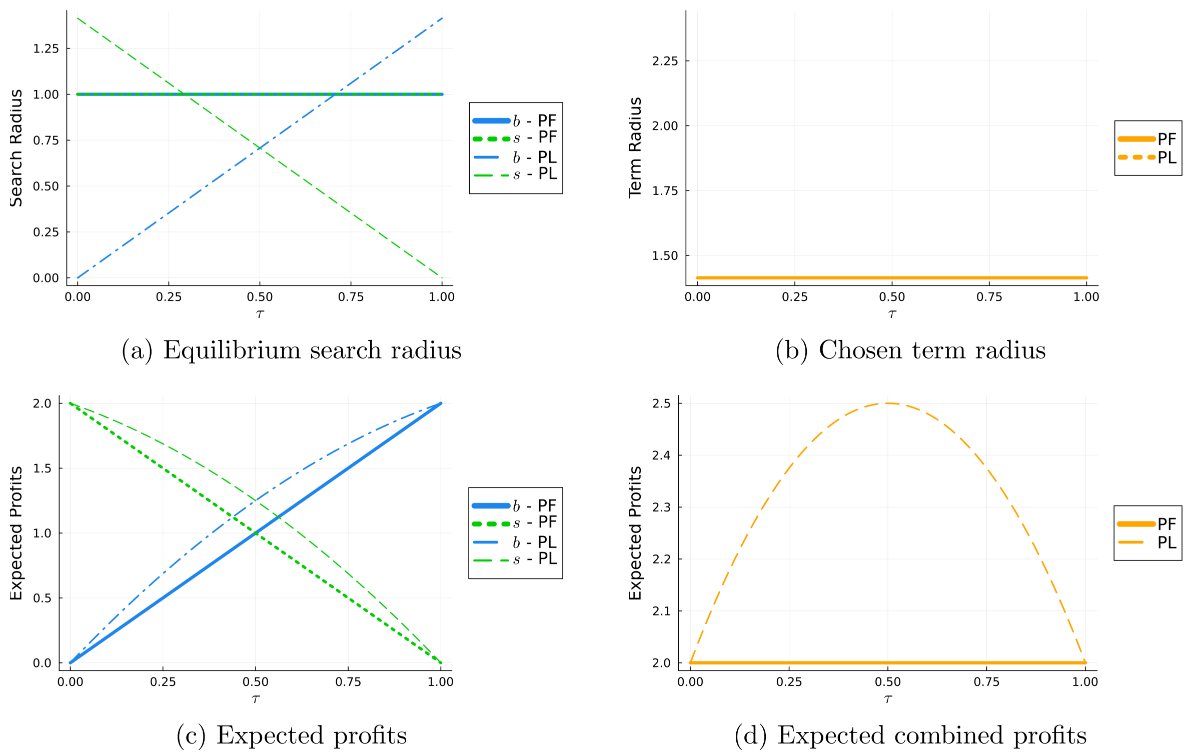
The term outside the brackets is strictly positive for $a>0$. Defining the bracketed term in the second line as $h(a)\equiv\pi a-0.5\sin(2\pi a)$, we have $h'(a)=\pi(1-\cos(2\pi a))$. Since $h'(a)$ is strictly positive for $a\in(0,0.25)$ and $h(0)=0$, we have that $h(a)>0$ for $a\in(0,0.25]$. Thus $\frac{\partial\frac{\pi}{a}\tan(\pi a)}{\partial a}>0$ over the same interval. In turn, this implies that $f(\cdot,\gamma_a)$ has one zero in $(0,\bar{a}]$ if $\gamma_a\in(\pi^2,\frac{\pi}{\bar{a}}\tan(\pi\bar{a})]$.

We now prove that this zero is in fact optimal. By a similar argument as in (ii), for the angle $a^*\in(0,\bar{a}]$ such that $\gamma_a=\frac{\pi}{a^*}\tan(\pi a^*)$, the function $f(a,\gamma_a)$ is positive (and therefore the firms' profits are increasing) for any $a<a^*$ and it is negative (implying firms' profits are decreasing) for $a>a^*$. Thus a^* and $-a^*$ are optimal for the firms.

Finally, for $\gamma_a>\frac{\pi}{\bar{a}}\tan(\pi\bar{a})$, the firms' first-order condition is positive (and therefore profits are increasing in a) for all $a\in(0,0.25]$. This implies that both the upper bound $\bar{a}$ and lower bound $-\bar{a}$ are optimal for sufficiently large γ_a.

A3 Additional figures

Figure A3.1: Comparative statics with respect to τ (endogenous angle search)



(a) Equilibrium search radius

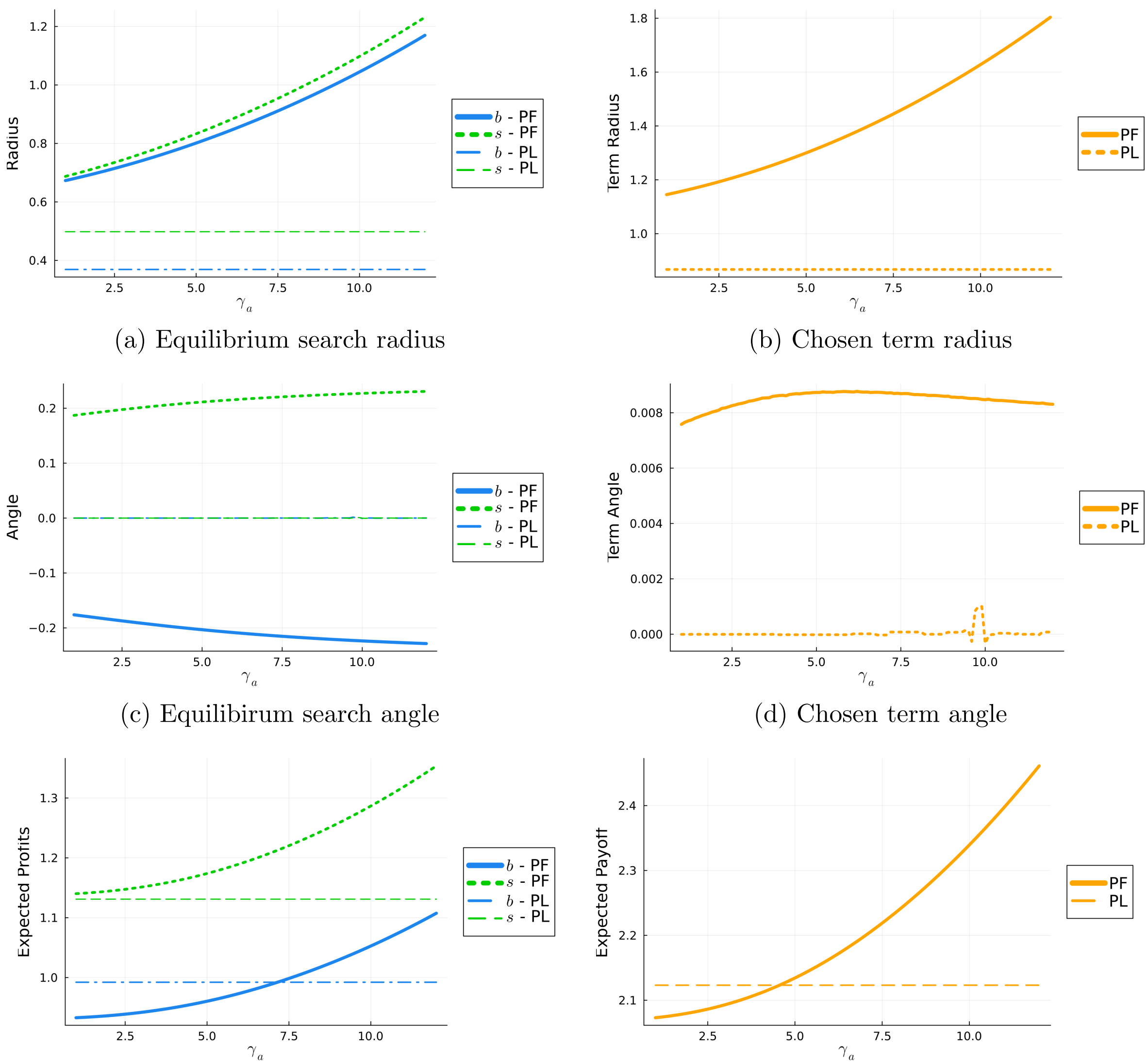
(b) Chosen term radius

(c) Expected profits

(d) Expected combined profits

Notes: The panels on the left-hand side plot the variable of interest for both firms b and s in the price-first ("PF") and price-first ("PL") games. The panels on the right-hand side depict the corresponding outcomes of the contract in both games, for the combined firms. The plots assume $\alpha = 2$, $\gamma_b = \gamma_s = 1$, $\gamma_a = 0$, $\pi_b = 2$, and $\pi_s = 1$.

Figure A3.2: Comparative statics with respect to γ_a (independent term shocks)



(a) Equilibrium search radius (b) Chosen term radius

(c) Equilibirum search angle (d) Chosen term angle

(e) Expected profits (f) Expected combined profits

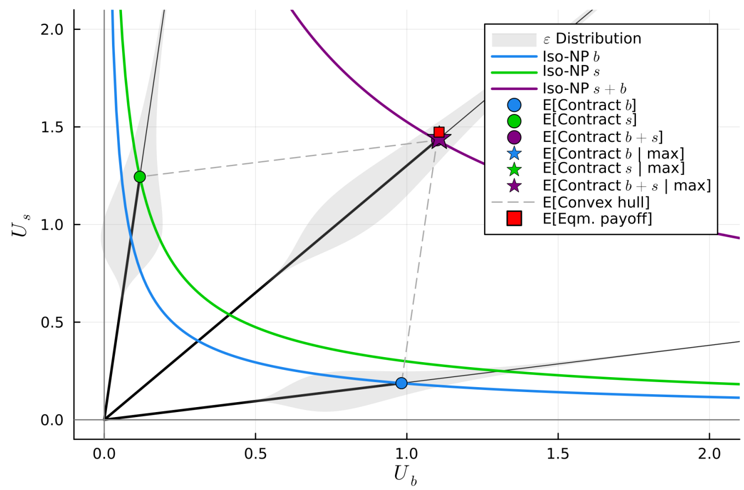
Notes: The panels on the left-hand side plot the variable of interest for both firms b and s in the price-first ("PF") and price-first ("PL") games. The panels on the right-hand side depict the corresponding outcomes of the contract in both games, for the combined firms. The plots assume $\tau = 0.45$, $\alpha = 2$, $\gamma_b = \gamma_s = 1$, $\pi_b = 2$, and $\pi_s = 1$.

A4 Equilibrium contract with unrestricted term search and independent productivity shocks

Figure A4.1 illustrates the bargaining game for the full model. In contrast to Figure 2, where ϵ's components are perfectly correlated, independent realizations of term-specific shocks lead to a different "shape" for the convex hull of every bargaining set; we therefore represent the variation due to ϵ with densities graphed along the radius of each term.

Figure A4.1 also shows the option value from variety: the red square representing the expected equilibrium payoff is closer to the top-right than any of the individual terms. This is also illustrated by the expected payoff to contract terms, represented by stars in the figure below: individual terms must have a favorable ϵ draw to be chosen, so their expected value to the firms is greater when conditioning on the terms being chosen. Note that the stars for the individual terms do not appear in the figure, since the value of the shock must be so extreme as to push the value of the joint payout to a higher iso-curve relative to the iso-curve of the combined term. For the combined term m_{bs}, this difference is only slight since it is a low-probability event that either individual term will be chosen over the combined term.

Figure A4.1: Firm payoffs in the bartering stage of the price-first game (unrestricted model)



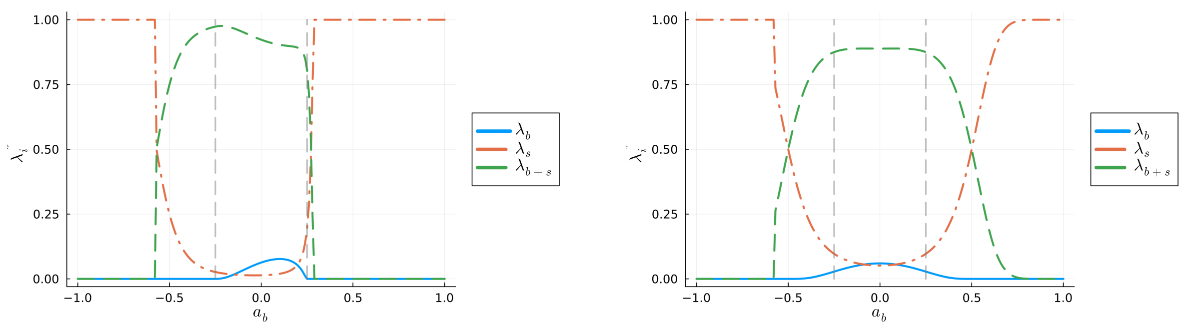
Notes: The plots assume $r_b = 1$, $r_s = 1.25$, $a_b = -0.19$, $a_s = 0.22$, $\alpha = 4$, and $\tau = 0.4$. These values are chosen for clarity of exposition and do not necessarily represent equilibrium actions. The blue and green stars are not shown on the figure, but instead lie far along their respective rays.

Figure A4.2 similarly provides intuition for how $\lambda_{j,G}$ varies with firm search decisions. Firm b and s both have a positive probability that their term will be chosen when searching within the first quadrant ($a_b \in [-0.25, 0.25]$, marked with dashed grey lines in the figures). This highlights how Lemma 1 does not hold in this setting since all terms have a positive probability of being chosen.[20] However, the combined term is preferred in expectation except when firm b searches in a sufficiently value-destroying direction and makes term s relatively more favorable.[21] While the term choice probabilities look broadly similar in panels (a) and (b), the price-last game has a nonzero probability of choosing term b even when a_b is outside the first quadrant; this is due to the redistribution of term payoffs in the price-last game.

20. Note that taking the limit as $\alpha \to \infty$ (thereby decreasing the variance of ϵ) pushes $\lambda_{bs} \to 1$.

21. Searching outside the first quadrant ($a_b \notin [-0.25, 0.25]$) results in some value destruction, but as shown in panel (b), this may still result in a term that is preferred to an individual term in expectation.

Figure A4.2: Term choice probabilities $\lambda_{j,G}$



(a) Price-first game

(b) Price-last game

Notes: The plots assume $r_b = 1$, $r_s = 1.25$, $a_s = 0.22$, $\alpha = 4$, and $\tau = 0.4$, and a_b varies to show the resulting probabilities that each term is chosen. These values are chosen for clarity of exposition and do not necessarily represent equilibrium actions.