Supply Chain Bargaining and Asset Prices

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Abstract

Any firm interacts with its customers and suppliers through pricing and investment decisions. This paper characterizes how vertical strategic interactions affect asset prices. We propose a real options model of strategic bargaining between a customer and a supplier that endogenizes how revenues are split over time. We find that firms’ revenue shares in the supply chain summarize their vertical bargaining power, and that relative larger firms with more diversified sales have higher bargaining power. Since negotiations are forward-looking, a firm with higher vertical bargaining power relies on transfer prices to extract her peer’s future continuation value. Hence vertical bargaining power enhances firms’ values, but also makes firms riskier. Comovement in expected returns between customers and suppliers is lower with large differences in their vertical bargaining power. The empirical evidence is consistent with each of these predictions.


Keywords: Supply Chain, Expected Returns, Investment, Customers, Suppliers, Bargaining.

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Introduction

Firms do not operate in isolation, but rather interact in multiple ways with other firms. An inevitable source of interaction is that of customer-supplier relations: any firm belongs to at least one supply chain of production. Customers and suppliers share common fundamentals, and mutually affect each other by deciding on production levels and investments, which determine transfer prices and also how firms split their joint value added. A natural question to ask is therefore which economic forces determine the way in which customers and suppliers split the value they create jointly, and how firms’ ability to extract revenues from supply chain peers, which we denote by vertical bargaining power, affects asset prices.

The study of customer-supplier interactions and their effect on asset prices is relevant in light of the empirical evidence that suggests that vertical relations drive a large fraction of merger activity (Fan and Goyal (2006), Ahern and Harford (2013)), and help predict stock returns (Cohen and Frazzini (2008), Menzly and Ozbas (2010)). Moreover, Ahern (2012) shows that relative gains by customers in vertical mergers are lower if the value of inputs required from suppliers is higher, and also if the value of customer purchases as a fraction of total supplier sales is lower. We propose a model that rationalizes the findings by Ahern (2012), and provide evidence in support our model’s novel predictions on how customer-supplier strategic interactions affect asset prices.

Several research questions motivate our study. First, what are the main economic forces at play in a given customer-supplier relation that drive their relative bargaining power while splitting revenues? Second, how does the vertical bargaining power of a supplier affect the ability of its customers to invest, and vice versa? Does a firm’s vertical bargaining power affect its exposure to systematic risk, and if so, how? How do vertical interactions affect the return comovement between customers and suppliers? And last, to what extent our findings differ from previous results in the literature, in which customer-supplier interactions are neglected or assumed non-strategic?

We address these questions by means of a partial equilibrium, real options model of strategic bargaining between a customer and supplier engaged in a bilateral monopoly, so that each firm is a monopolist in its own product market. While bilateral monopolies are rare in the strict sense, the model provides an ideal setting to study how firms behave strategically with buyers and suppliers to preserve their value (Porter (1998)). Each firm has an option to invest and grow
their business irreversibly, and firms’ operating profits are such that firms’ installed capacities are strategic complements. Firms operate at full capacity and bargain with their peer on the input price of the customer each time the installed capacity of the supply chain pair increases. Since firms inevitably need each other to develop the growth opportunities in the supply chain, the agreement outcome is weakly preferrable to the disagreement outcome while bargaining. The model endogenizes how revenues are split over time between customers and suppliers, and characterizes a firm’s ability to extract supply chain revenues as a function of a sorting condition on its production technology and sales segmentation.

The paper makes three main contributions. Our first contribution is to characterize the economic forces that drive firms’ bargaining power in customer-supplier relations, by means of a strategic bargaining game in a real options framework. Textbooks on bilateral monopoly solve for firms’ revenue shares in equilibrium using the axiomatic Nash bargaining solution, which takes firms’ relative bargaining power as exogenously given. The Nash bargaining solution assumes from the start firms’ revenue shares in equilibrium.\(^1\) Using a real options model with forward looking negotiations, we endogenize the revenue shares of customers and suppliers in equilibrium by considering firms’ continuation values under all possible alternative strategies (Stahl (1972), Rubinstein (1982)). In our model, a firm’s revenue share captures the industrial organization forces at play determining its relative bargaining power in a supply chain relation. Firms’ revenue shares reflect their relative vertical bargaining power in the supply chain, just as market shares capture firms’ relative horizontal market power in product markets.

The model predicts that vertical bargaining power is determined by two types of characteristics. The revenue shares of both firms vary with common supply chain characteristics such as the demand elasticity downstream, the input intensities in firms’ production processes, and the volatility of profit shocks. More importantly, the cross-sectional differences in firms’ revenue shares within a supply chain pair depend on the heterogeneity in installed capacities, differences in investment costs, and also on differences in firms’ ability to diversify sales. Seminal papers in the economics literature on strategic bargaining show that higher bargaining power can be driven by agents’ relative lower impatience or discount rate (Rubinstein, 1982), and also by differences in agents’ payoffs in case of

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\(^1\)As explained in Nash (1953), axiomatic methods state properties of the solution that fully determine the solution. See Chapter 18 in Mas-Collel et al. (1995) for a summary of axiomatic Nash bargaining games.
disagreement (Binmore et al., 1986). Consistent with these studies, we find that firms with lower initial scale of production or lower investment costs are more impatient to grow, and hence more willing to forgo larger fractions of value through transfer pricing to invest earlier. Also, firms have more vertical bargaining power if they obtain profits from segments or industries different from the one in which they bargain. Diversified sales capture outside opportunities (Whinston, 2003).

The predictions of our model on what determines firms’ vertical bargaining power and hence which firm extracts more supply chain value in equilibrium are opposite to those in real options models of strategic interaction in which firms compete for market share in the same product market (Pawlina and Kort (2006), Mason and Weeds (2010), and Carlson et al. (2014)). In these studies, firms own their growth options, and hence they invest and gain market share faster if their investment costs are lower, or their installed capacity is relatively low. In contrast, in our model, firms’ growth options are jointly developed. As a result, firms that are relatively larger before negotiation take place are more patient to invest, and hence extract more value from their supply chain peers. The notion that the value of jointly developed growth opportunities is allocated according to firms’ relative bargaining power is consistent with the evidence on vertical mergers in Ahern (2012). More importantly, it relates to the observation in Saloner et al. (2001) that a firm not only needs to create value, but it must also be able to capture the value it creates.

The second contribution of the paper is to characterize how customer-supplier strategic interactions affect their expected returns. In the model, the firm with higher vertical bargaining power extracts a larger fraction of the joint future value of the supply chain. This is in contrast with static stylized conjectures in the literature, in which, for instance, a monopsonist may lead a supplier to bankruptcy by requesting low prices that reduce the value of its supplier’s assets in place. Since negotiations are forward looking, our model shows that firms with higher vertical bargaining power extract future (as opposed to current) peer value. The crucial difference in these arguments relies the corresponding asset pricing implications: the stylized view implies that firms with less vertical bargaining power are relatively riskier, while in our model and also in the data these firms are relatively safer. We predict that vertical bargaining power makes firms riskier, as they absorb the exposure to systematic risk of their supply chain peers through transfer pricing.

The model makes additional predictions on vertical relations and firms’ expected returns. The first applies within a given customer-supplier relation, and relates to how vertical interactions
affect the dynamics of expected returns. In the model, the correlation between the returns of customers and suppliers is lower with large differences in their relative vertical bargaining power. The underlying logic for this result is that rent extraction is more severe when there are larger differences in firms’ installed capacities or sales segmentation. The model also highlights other economic forces that affect firms’ risk loadings across supply chain pairs. In particular, firms’ risk loadings across supply chain pairs vary with the elasticity of demand downstream, the share of inputs required by customers to produce their final good, the volatility of supply chain shocks, and the capital intensity in the production processes.

The third contribution of the paper is to provide evidence in support of the model. Our empirical findings add to the literature on industrial organization and asset prices, which has primarily focused on horizontal (as opposed to vertical) interactions. The empirical analyses consider pairs of customer and supplier industries as defined by the Bureau of Economic Analysis (BEA) input/output tables. We use two different types of measures to proxy for firms’ vertical bargaining power. In the model, a firm’s current revenue share captures its current vertical bargaining power, while the difference between a firm’s book-to-market asset ratio (or inverse average Q) and that of its peers in the same supply chain pair captures its future vertical bargaining power. We use firms’ book-to-market ratios to capture cross sectional differences in firms’ continuation values. Moreover, we use the information by BEA to construct two proxies of bargaining power jointly capturing firms’ revenue shares by industry, and firms’ operating hedge due to sales to other industries.

In our empirical tests, we document that the difference between the returns of customers and suppliers is higher when customers have lower book-to-market ratios. Through the lens of the model, this implies that supply chained industries with relatively higher continuation value and hence higher bargaining power are riskier. Similarly, the returns of customers are relatively higher than those of their suppliers when their sales are more diversified, and hence they have less skin in the game in the segment shared with their suppliers. We also find that the correlation between the returns of customers and suppliers is lower as the cross sectional standard deviation in vertical

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2 A relevant exception is Gofman et al. (2018). We elaborate on this study later in this section.
3 While supply chain interactions can also be intra-industry, our empirical tests focus on the inter-industry margin.
4 In a related study of strategic interaction in product markets, Bustamante (2015) finds that differences in firms’ market to book ratios within the same industry capture their relative competitive advantage.
5 We follow Ahern (2012) and construct a variable equal to the dollar value of supplier inputs relative to customer sales, and another variable measuring the diversification of supplier sales. See details in Section 3.
bargaining power increases. This finding suggests that vertical interactions affect the dynamics of asset prices. Last, we provide evidence consistent with the investment channel driving the asset pricing predictions of the model. Customers have significantly higher investment-to-capital ratios than their suppliers if their market to book ratio is relatively higher, and also if their sales are more diversified than those of their supply chain peers.

Related Literature

The paper relates to multiple strands of the economics, management and finance literatures. The model contributes to the dynamic games of strategic bargaining by Rubinstein (1982) and Binmore et al. (1986), who show how differences in the impatience and disagreement payoffs determine agents’ relative bargaining power in infinitely repeated games. The novelty of solving for a strategic bargaining game between a customer and a supplier in a real options setting is that their relative bargaining power is driven by observable characteristics such firms’ scale before negotiations take place, and their sales segmentation. Our findings on the determinants of vertical bargaining power relate closely to the discussions in Porter (1998) and Saloner et al. (2001) on firms’ strategic behavior to preserve their value in supply chains.

The model contributes to the real options literature of games of strategic interaction, which focuses on duopoly games in which firms compete in capacity. A closely related study is that by Weeds (2002). We contribute to these studies by analyzing the effects of vertical strategic interaction on firms’ option exercise strategies. The model relates to the studies by Carlson et al. (2014) and Bustamante (2015) studying the link between strategic behavior in product markets and firms’ expected returns. It also adds to the studies on operating leverage by Novy-Marx (2011) and Hackbarth and Johnson (2015), as we study how diversified sales yield an operating hedge that both attenuates risk and enhances vertical bargaining power.

The paper adds to the young literature on vertical relations and asset prices. The model rationalizes the findings on vertical merger gains and bargaining power in Ahern (2012). Through

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6 We consider two alternative measures of cross sectional variation in vertical bargaining power, as proxied by differences in book-to-market ratios within a supply chain pair, or differences in sales segmentation. See Section 3 for further details.


8 Weeds (2002) elaborates on firms’ incentives to delay investment in a preemption game in which firms’ products are strategic substitutes. We study firms’ incentives to delay investment when firms’ products are strategic complements and yet firms bargain over transfer prices. See Section 1.
the lens of our model, the measures of bargaining power proposed by Ahern (2012) capture firms’ operating hedge due to outside options, and also firms’ revenue shares. Moreover, Gofman et al. (2018) construct a measure of upstreamness that sorts firms according to relative position in the production network, and then document that more upstream firms are on average riskier than more downstream firms. The authors explain this fact by arguing that firms that operate in downstream layers face more value destruction than firms operating further upstream. We contribute to Gofman et al. (2018) by showing how firms’ relative bargaining power in customer-supplier relations affects asset prices, irrespective of firms’ location in the supply chain. We also study the micro foundations of firms’ vertical bargaining power.

The findings in our paper relate more broadly to the literature on product market competition and asset prices. Hou and Robinson (2006), Bustamante and Donangelo (2017), Loualiche (2017), Corhay et al. (2017), and Babenko et al. (2018) study the link between product market competition and returns. By construction, our model cannot explore the effect of product market competition on supply chain asset prices, as it focuses on a bilateral monopoly. We elaborate instead on how strategic interactions in supply chains affect asset prices. Hoberg and Phillips (2010) find that returns comove more positively in competitive industries. We find that returns comove more positively in supply chain pairs with low spreads in vertical bargaining power.

Last, the paper belongs to the literature exploring the interaction between firms’ production decisions, investment decisions, and asset prices. Seminal papers include Cochrane (1991), Berk et al. (1999), Kogan (2001), Carlson et al. (2004), Zhang (2005), Novy-Marx (2007), and Kogan and Papanikolaou (2014). The paper also relates broadly to the growing literature on production networks that exploits the complementarity in operating profits of supply linked firms to explain how macroeconomic shocks propagate over the economy. Some of these studies include Acemoglu et al. (2012), Barrot and Sauvagnat (2016) and Ozdagli and Weber (2017).

1 Basic Model

1.1 Main Assumptions

Vertically related incumbent firms. We model the equilibrium effects of customer-supplier interactions on asset prices by considering two firms linked through a supply chain pair: firm $U$
upstream and firm $D$ downstream. Each firm $j = U, D$ operates a monopoly in their own product market. The supply chain is such that firm $U$ produces an intermediate good which is an input of production for firm $D$. Since firm $D$ is the single client of firm $U$, firm $D$ is also a monopsonist, such that firms $U$ and $D$ are engaged in a bilateral monopoly. Both firms acknowledge their ability to affect the price of the input of production of firm $D$, and have incentives to behave strategically.

**Sources of firm value.** Firms are run by managers that maximize shareholder value. We determine the firms’ values as the expected discounted stream of their risky operating profits. To compute firms’ values, we consider an exogenous pricing kernel, following Berk et al. (1999). The dynamics of the pricing kernel $\xi$ are given by

$$\frac{d\xi_t}{\xi_t} = -rdt - \eta dW_t$$  \hspace{1cm} (1)

where $r > 0$ is the instantaneous risk free rate, $\eta > 0$ captures the market price of risk, $dW_t$ is a Wiener process that represents the only source of systematic risk, and $W_0$ is strictly positive.

Operating profits capture revenues minus the costs of production. We assume that each firm produces homogeneous goods and operates at full capacity. Production functions are Cobb-Douglas with constant returns to scale as in Acemoglu et al. (2012). The production function of firm $j$ or $Q_{jt}$ is given by

$$Q_j[M_{jt}, K_{jt}] = (M_{jt})^{\alpha_j} (K_{jt})^{1-\alpha_j}$$

where the parameter $\alpha_j \in (0, 1)$ captures the share of the input factor $M_{jt}$ in the production process of firm $j$, $K_{jt}$ is the amount of capital installed in firm $j$ at time $t$, and $1 - \alpha_j$ corresponds to the capital intensity of firms of type $j$. The existence of a supply chain implies that $M_{Dt}$ is an intermediate good such that $M_{Dt} \equiv Q_U[M_{Ut}, K_{Ut}]$.

Operating profits are affected by two different types of stochastic shocks. The demand function of firms downstream requires that the market price of final products sold downstream $p_{Dt}$ equals

$$p_{Dt} = Y_t (Q_{Dt})^{-\frac{1}{\epsilon}}$$

where $\epsilon > 1$ is the elasticity of demand downstream, $Q_{Dt}$ is the total production downstream.
at time $t$, and $Y_t$ is a stochastic demand shock. The downstream demand shock $Y_t$ follows a geometric Brownian motion with drift $\mu_Y$ and diffusion $\sigma_Y$. The drift $\mu_Y$ captures the expected demand growth for firms downstream. The diffusion $\sigma_Y > 0$ represents the level of downstream exposure to the systematic source of priced risk $dW_t$.

The marginal costs of production of firms upstream are also stochastic and given by $cX_t$, where $0 < c < 1$ and the upstream cost shock $X_t$ follows a geometric Brownian motion with drift $\mu_X$ and diffusion $\sigma_X$. The parameter $\sigma_X > 0$ captures priced upstream exposure to variation in costs of production.\footnote{For simplicity, we assume that all the variation in demand shocks downstream and cost shocks upstream is priced. The qualitative predictions of the model remain the same if only a portion of the these risks is priced.} The initial values $X_0$ and $Y_0$ are assumed sufficiently low so that all growth opportunities in the supply chain are strictly positive at $t = 0$.

We further assume that each firm $j = U, D$ has the option to increase their initial installed capacity $K_{j0} \equiv K_j$ to $\Lambda_j K_j$ at a given point in time, where $\Lambda_j > 1$. The decision to invest is irreversible and entails benefits and costs. Upon investment, firms benefit from an increase in the scale of their profits. Firms also incur a lump sum investment cost $\kappa_j K_j > 0$.

**The problem of firms.** Managers maximize shareholder value by choosing the amount of inputs of production $M_{jt}$, as well as the investment thresholds $z_j$. The investment thresholds $z_j$ determine the optimal stopping times $\tau_j$ at which firms exercise their investment opportunity and increase their installed capacity from $K_j$ to $\Lambda_j K_j$. Since firms operate in a bilateral monopoly, they engage in bargaining to settle the price $p_{Ut}$ for the input of production $M_{Dt}$ in equilibrium.\footnote{Unlike a downstream firm that takes prices as given, a monopsonist downstream understands that increasing the demand for inputs of production also increases the market price $p_{Ut}$. Hence firm $D$ demands a lower amount of $M_{Dt}$ in equilibrium.}

**Strategic bargaining game.** Supply chain managers negotiate to settle on the input price downstream $p_{Ut}$ each time a firm modifies its installed capacity. In this sense, firms’ negotiation of the price $p_{Ut}$ is forward looking. Since firms’ investments are irreversible and firms operate at full capacity, in equilibrium the agreed expected price $p_{Ut}$ remains the same unless the total installed capacity of the supply chain increases. As we elaborate below, we re-express the outcome of each negotiation over the price $p_{Ut}$ for firm $j$ in terms of its revenue share, or the fraction $\theta_{j,\tau}$ of the total revenue of the supply chain pair that is allocated to firm $j$ at the stopping time $\tau$.\footnote{See the proof of Lemma 1 in the Appendix for further details on the mapping between $p_{Ut}$ and $\theta_{j,\tau}$.}
The real options bargaining game endogenizes the stopping times \( t = \tau \) at which firms negotiate. The model also predicts which firm in the supply chain moves first to make an offer to its counterpart, and which firm decides instead to either reject or accept the offer of their supply chain peer. This is contrast with existing games of strategic bargaining games in the literature, in which the timing and ordering of the actions by firms is exogenously given.\(^{12}\)

At any time \( t = \tau \) in which firm \( j \) decides to expand its capacity, firm \( -j \) receives a revenue sharing offer which she may accept or reject. The bargaining game determines the fraction \( \theta_{j,\tau} \) of the total revenue of the supply chain pair that is allocated to firm \( j \) at the stopping time \( \tau \). The operating profits of each firm \( j \) are equal to \( \theta_{j,\tau} (\Pi_U + \Pi_D) \) upon agreement at any time \( t \geq \tau \). The set of possible agreements of the bargaining game at \( t = \tau \) is given by:

\[
\Theta = \{ \{\theta_{U,\tau}, \theta_{D,\tau}\} | \forall \tau > 0, \theta_{j,\tau} \geq 0, \theta_{U,\tau} + \theta_{D,\tau} \leq 1 \}.
\]

The strategic bargaining game also admits the possibility that the players do not reach an agreement. We follow Binmore et al. (1986) and define such case as the disagreement outcome. If firm \( -j \) rejects the offer of firm \( j \), and since firms depend on either the supply or demand of their counterpart, both firms continue to produce the amounts agreed in their previous contract cycle which represents their status quo. Paraphrasing, the reservation value of firms in case of disagreement equals the value of their assets in place.

The nature of the bargaining game is such that, for any possible negotiation time \( t = \tau \), there exists a conflict of interest between firms \( U \) and \( D \): each firm \( j \) prefers a higher share of the total revenue. This conflict of interest admits a solution since reaching an agreement is always weakly welfare improving for both firms. Anticipating, firms’ growth opportunities are strategic complements, and hence there exist mutually beneficial agreements \( \theta_{j,\tau} \in \Theta \) such that firms weakly prefer to negotiate at time \( \tau \) and obtain \( \theta_{j,\tau} \) instead of allowing for the disagreement outcome. All parameters are common knowledge, so that there is complete information.

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\(^{12}\)See, for instance, Stahl (1972), Rubinstein (1982) and Binmore et al. (1986).
1.2 Operating Profits

We begin our analysis by re-expressing firms’ operating profits as a function of common fundamentals and the revenue shares $\theta_{j,\tau}$. Since there are no direct costs of bargaining, firms’ revenue shares in equilibrium sum up to one.\footnote{By assumption, the bargaining process is frictionless. No direct bargaining costs preclude firms from negotiating over the total supply chain revenue generated at times in which firms expand capacity.} As we show in the Appendix, this property ensures that the functional form of firms’ operating profits is qualitatively the same for any given revenue share $\theta_{j,\tau}$. We solve for firms’ revenue shares in equilibrium later in this section.

**Lemma 1** Let $\theta_{j,\tau}$ be the revenue share of firm $j$ as agreed in the negotiation cycle occurred at time $\tau \leq t$. For any given revenue share $\theta_{j,\tau}$, operating profits are such that $\Pi_j [Y_t, z_t] \equiv Y_t \times \pi_j [Z_t]$, where the function $\pi_j [Z_t]$ is so that

$$\pi_j [Z_t] \equiv \theta_{j,\tau} \times \Omega \times Z_t \times (K_{U_t})^\psi (K_{D_t})^\omega,$$

while $Z_t \equiv (Y_t/X_t)^{(1-\alpha_D)/(1-\alpha_D)}$ is a function of ratio of the downstream demand shock $Y_t$ and the upstream cost shock $X_t$, the parameters $\Omega > 0$ and $0 < \omega < 1$ are defined in the Appendix, and the parameter $0 < \psi < 1$ is such that $\psi \equiv \omega \alpha_D (1-\alpha_U) (1-\alpha_D)^{-1}$.

Lemma 1 summarizes the properties of the operating profits of firms $U$ and $D$ in a bilateral monopoly for any given revenue share $\theta_{j,\tau}$. The first property is that firms’ operating profits are driven by variation in the same state variables $Y_t$ and $Z_t$. This is consistent with the study by Acemoglu et al. (2012) on production networks. Assuming that firms operate in contestable markets, Acemoglu et al. (2012) show that a positive technology shock to one firm creates a positive externality to other firms in the same production network. In our basic model, firms $U$ and $D$ operate in a single business segment and do not interact with other firms, so that there is perfect positive correlation in firms’ profits in equilibrium.\footnote{We allow firms to operate in multiple business segments in Section 2.}

Lemma 1 shows that, for any given revenue share $\theta_{j,\tau}$, the profits of firm $j$ are increasing in the capacity choices of its peer firm $-j$ in the same supply chain. Paraphrasing, firms’ growth opportunities are *strategic complements*. Taking firms’ revenue shares as given, an increase in the installed capacity of firm $D$ increases the operating profits of firm $U$ and viceversa. This is in
contrast with the existing literature on real options games of strategic interaction, which focuses on the case of two firms competing in capacity in the same product market, and whose products are strategic substitutes.\footnote{See, for instance, Weeds (2002), Pawlina and Kort (2006), Mason and Weeds (2010), and Carlson et al. (2014).}

1.3 Firms’ Values

For any given investment threshold $z_j$ and revenue shares $\theta_{j,\tau}$, the value of firm $j$ at time $t$ or $V_{jt}$ equals the expected present value of its risky profits. We determine the value of the firm using the exogenous pricing kernel in Equation (1).

**Lemma 2** The value of any firm $j$ in the supply chain pair is given by $V_j[Y_t, Z_t] \equiv Y_t \times V_j[Z_t]$ where the function $V_j[Z_t] \equiv V_{jt}$ for any investment strategy $z_j$ is given by

\[
V_j[Z_t] = \begin{cases} 
  \frac{\pi_{jt}^-}{\delta} + \left( \frac{\pi_{jt}^+}{\delta} - \frac{\pi_{jt}^-}{\delta} - \kappa_j K_j \right) + \Delta \pi_{jt}^- + \left( \frac{\Delta \pi_{jt}^+}{\delta} \right)_{Z_t = z_j} & \text{if } Z_t \leq z_j \\
  \frac{\pi_{jt}^+}{\delta} + \Delta \pi_{jt}^+ & \text{if } Z_t > z_j 
\end{cases}
\]

where $v > 1$ is defined in the Appendix, $\Delta \pi_{jt}^-$ is the expected change in instantaneous profits of firm $j$ due to an investment by firm $-j$ before firm $j$ invests, and $\Delta \pi_{jt}^+$ is the expected change in instantaneous profits of firm $j$ due to an investment by its competitor after firm $j$ invests.

Lemma 2 characterizes the value of firm $j$ as a function of its own investment strategy and the investment strategy of its peers in the supply chain. The value of firm $j$ before it exercises its own growth opportunity corresponds to the first line in Equation (2). The first and second terms in Equation (2) reflect that the value of firm $j$ depends on its own strategy $z_j$. The first term corresponds to the value of a growing perpetuity of cash flows generated by its assets in place. The second term corresponds to the value of its investment opportunities or growth options. The third and fourth terms of the preinvestment value of firm $j$ reflect instead the impact of the investment strategy of firm $-j$ on $V_{jt}$. The investment strategy of firm $-j$ affects the value of firm $j$ through the expected changes in future profits $\Delta \pi_{jt}^-$ or $\Delta \pi_{jt}^+$. As we elaborate below, a direct implication of the outcome of the bargaining game is that $\Delta \pi_{jt}^- \geq 0$ and $\Delta \pi_{jt}^+ \geq 0$ in equilibrium.
1.4 Expected Returns

We define the instantaneous expected excess asset return $\mathcal{R}$ as the drift of the gains process of firm $j$ at time $t$, so that
\[
\mathcal{R}_{jt} \equiv E_t \left[ \frac{dV_{jt}}{V_{jt}} \right] \frac{1}{dt} + \frac{\Pi_{jt}}{V_{jt}} = \beta_j \eta,
\] (3)
where $\eta$ is the market price of risk, and $\beta_j$ is the implied systematic risk loading of firm $j$ at time $t$. Equation (3) shows that the asset pricing implications for expected returns $\mathcal{R}$ are the same as those for the systematic risk loading $\beta_j$. Consequently, we discuss the asset pricing implications of the model by focusing on the systematic risk loading $\beta_j$.

Lemma 3 For any investment strategy $z_j$, the risk loading of any firm $j$ in the supply chain pair is given by $\beta_j[Z_t]$ so that
\[
\beta_j[Z_t] = \sigma_Y + \sigma_Z \frac{\chi_j[Z_t]}{\delta} + \nu \sigma_Z \times \left( 1 - \frac{\chi_j[Z_t]}{\delta} \right)
\] (4)
where the function $\chi_{jt}$ is the ratio of operating profits $\Pi_{jt}$ to firm value $V_{jt}$ or earnings-to-price ratio, and both $\sigma_Z$ and $\nu > 1$ are defined in the Appendix.

Equation (4) shows that the risk loading $\beta_j$ is a linear function of its earnings-to-price ratio $\chi_{jt}$. For both firms in the supply chain, the risk loading of assets in place due to variation in $Z_t$ is captured by $\sigma_Z$, or the diffusion of the variable $Z_t$. Similarly, for both firms in the supply chain pair, the risk loading of growth opportunities is given by the product $\sigma_Z \nu$, where $\nu > 1$ indicates that growth opportunities are riskier than assets in place. The earnings-to-price ratio therefore weights the risk loadings on assets in place and growth opportunities, in proportion to their contribution to the expected returns of the firm.

Equation (4) further shows that a firm’s exposure to systematic risk depends on the decisions of both customers and suppliers. Given that a firm’s earnings-to-price ratio captures the relative contribution of a firm’s assets in place to its exposure to systematic risk, changes in installed capacities all over the supply chain pair affect firm’s exposure to systematic risk. Changes in firms’ earnings-to-price ratios lead to changes in the relative weights of assets in place and growth options in Equation (4). Since the risk loadings of assets in place and growth opportunities are strictly different, expected returns vary over time with changes in the capital of customers and suppliers.
1.5 Equilibrium Investment Strategies

The model admits two types of equilibria in pure strategies: a joint investment equilibrium, and a sequential investment equilibrium. We focus on equilibria in pure strategies. The equilibrium concept is Bayes-Nash. The state of the supply chain pair is described by the history of the stochastic shock $Z_t$. At any point in time, a history is the collection of realizations of the stochastic process $Z_s$, $s \leq t$, and the actions taken by firms $U$ and $D$. The investment strategy of each firm $j$ maps the set of histories of the supply chain into the set of actions $z_j$ for firm $j$. Before investment, firm $j$ responds immediately to the investment decisions of its peers in the same supply chain pair. This yields Nash equilibria in state dependent strategies of the closed-loop type. Upon investment, firm $j$ cannot take any other action.

We follow Weeds (2002) and we assume that firms follow Markov strategies such that their actions are functions of the current state $Z_t$ only. Other non-Markov strategies may also exist; however, if one firm follows a Markov strategy, the best response of the other firm is also Markov. We consider the set of subgame perfect equilibria in which each firm’s investment strategy, conditional on its competitor’s strategy, is value maximizing. A set of strategies that satisfies this condition is Markov perfect. Subgame perfection requires that each firm’s strategy maximizes its value conditional on its peer’s strategy.

As mentioned in Lemma 1, the bargaining game is such that $\theta_{j,\tau} = 1 - \theta_{-j,\tau}$ at any stopping time $\tau$. Due to this property and for brevity, we refer hereafter to the revenue share of firm $U$ or $\theta_{U,\tau}$ while characterizing revenue shares for both firms in equilibrium. We solve for the equilibrium outcome by considering an additional assumption that specifies the source of heterogeneity in firms’ production technologies.

Assumption 1 $\Lambda_j = \Lambda, K_{j0} \equiv K, \theta_{j,0} = \frac{1}{2},$ and $\kappa_U < \kappa_D$.

Assumption 1 states that firms share the same underlying parameters, with the exception of their investment costs $\kappa_j$. Anticipating, firms with relatively lower investment costs $\kappa_j$ are more impatient and therefore have less bargaining power. In the Appendix, we consider the alternative specification in which firms have the same investment costs and differ instead in their installed capacity before investment $K_j$. In this case, smaller firms are more likely to invest earlier than larger firms. Both differences in investment costs $\kappa_j$ and the initial installed capacity $K_j$ yield the
same qualitative results: all else equal and by construction, firms have higher costs of investment if their initial installed capacity is higher. We choose $\kappa_j$ as a source of heterogeneity (instead of $K_j$) for the sake of brevity.

Given Assumption 1, the solution to the bargaining game is described by the investment strategy of each firm $z_j$, the intra-supply-chain standard deviation in firms’ investment costs $\sigma_\kappa \equiv \frac{|\kappa_D - \kappa_U|}{2}$, and the revenue shares $\theta_{U,\tau}$ determining the proceeds received by each firm in equilibrium. In what follows, we characterize the two equilibria of the game in pure strategies, and then apply an equilibrium refinement to derive testable predictions.

1.5.1 Sequential investment equilibrium

We solve for the equilibrium outcome using a sorting condition and participation constraints. This solution approach is heavily used in the literature of mechanism design and games of strategic interaction. The sorting condition ranks firms according to their ability to invest earlier than their peers. Given Assumption 1, we derive a sorting condition when firms differ exclusively in their investment costs $\kappa_j$ so that

$$\frac{\partial}{\partial \kappa_j} \left( \frac{\partial V_{jt}}{\partial z_j} \right) > 0, \quad (5)$$

where the inequality in Equation (5) applies to any possible investment strategy $z_j$.

The sorting condition in Equation (5) implies that firms with lower investment costs find it more beneficial to invest earlier than their competitors. If a sequential investment equilibrium occurs, then it must be the case that firm $U$ invests earlier. Moreover, the bargaining game is such that the differences in firms’ relative impatience affect their revenue shares in equilibrium. Since firm $U$ has a lower investment cost, firm $U$ is the first to make a revenue sharing offer to firm $D$, either when firms invest sequentially or simultaneously. Firm $U$ is relatively more impatient to invest, and hence more willing to forgo future expected value and offer a higher revenue share to firm $D$ in exchange of an early exercise of its growth opportunity.

An additional feature of the bargaining game that is key to understand the sequential equilibrium outcome relates to the ability of firms to reject a revenue sharing offer of their supply chain peer at any stopping time $\tau$. When firms invest sequentially, firm $-j$ has the ability to reject the

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16See Fudenberg and Tirole (1991) for a discussion on the use of sorting conditions in games of strategic interaction. Bustamante (2015) considers a real options model of strategic interaction which is solved using sorting conditions.
offer of firm \( j \) at the investment threshold of firm \( j \). Upon rejection, firm \( j \) cannot develop her growth option and both firms maintain their levels of production unchanged. Hence firm \(-j\) relies on the threat of rejection to extract future continuation value from firm \( j \).

We solve the sequential investment equilibrium strategies by backward induction. Consider first the optimal investment strategy of firm \( D \) at the threshold \( z^s_D > z^s_U \). When firm \( D \) is eager to invest, firm \( U \) uses its ability to reject the offer of firm \( D \) to extract all its future growth option value. As a result, firm \( D \) chooses the threshold \( z^s_D \) and the revenue share \( \theta_{D,\tau_D^s} \) in equilibrium so as to maximize the value of firm \( U \): any other strategy would result in rejection. To derive the optimal investment threshold \( z^s_D \) and the revenue share \( \theta_{D,\tau_D^s} \), we consider two conditions. First, we consider the participation constraint of firm \( D \) to be binding at \( t = \tau_D^s \) so that

\[
V^s_D[Z_t] | Z_t = z^s_D = \frac{\pi^*_D[z^s_D]}{\delta},
\]

where Equation (6) implies that the investment of firm \( D \) yields zero future expected value to firm \( D \). Second, firm \( U \) maximizes its value the investment threshold \( z^s_D \) so that

\[
\frac{\partial V^s_U[Z_t]}{\partial z^s_D} | Z_t = z^s_D = 0.
\]

Since firm \( U \) extracts all future expected value (Equation (6)), firm \( U \) internalizes the joint surplus while choosing the optimal investment threshold (Equation (7)).

Consider now the optimal investment strategy of firm \( U \) at the threshold \( z^s_U \). When firm \( U \) is eager to invest, firm \( D \) uses its ability to reject the offer of firm \( U \) to extract its future expected option value: this includes the future value that firm \( U \) will extract from firm \( D \) at \( t = \tau_D^s \). Since firm \( U \) is relatively more impatient and hence has less bargaining power, firm \( U \) chooses the threshold \( z^s_U \) and the revenue share \( \theta_{U,\tau_U^s} \) in equilibrium so as to maximize the value of firm \( D \). To derive the optimal investment threshold \( z^s_U \) and the revenue share \( \theta_{U,\tau_U^s} \), we consider the participation constraint of firm \( U \) to be binding at \( t = \tau_U^s \) so that

\[
V^s_U[Z_t] | Z_t = z^s_U = \frac{\pi^*_U[z^s_U]}{\delta},
\]

where Equation (8) implies that the investment of firm \( U \) yields zero present future value to firm
Moreover, firm $D$ maximizes its value at the investment threshold $z^s_U$ so that

$$\frac{\partial V^s_D[Z_t]}{\partial z^s_U}\bigg|_{Z_t=z^s_U} = 0. \quad (9)$$

The investment threshold $z^s_U$ is such that firm $D$ internalizes all joint surplus in the supply chain (Equation (8)), while deciding when to invest (Equation (9)).

**Proposition 1 (Sequential investment equilibrium strategies)** The sequential investment subgame-perfect equilibrium in a bilateral monopoly with firms $j = U, D$ and $\kappa_U < \kappa_D$ is such that the investment thresholds $z^s_U < z^s_D$ are equal to

$$z^s_U = \frac{\kappa_U K}{\Omega(\Lambda^\psi - 1) K^\psi + \omega} \frac{\delta v}{\psi - 1}, \quad \text{and} \quad z^s_D = \frac{\kappa_D K}{\Omega(\Lambda^\psi - 1) K^\psi + \omega} \frac{\delta v}{\psi - 1}.$$

The corresponding sharing rules $\theta_{U,\tau^s_U}$ and $\theta_{U,\tau^s_D}$ are given by

$$\theta_{U,\tau^s_U} = 1 - \frac{1}{v} + \left(\frac{1}{v} - \frac{1}{2}\right) \Lambda^{-\psi} + \frac{\kappa_D(\Lambda^{-\psi} - 1)}{\kappa_U} \left(\frac{\kappa_U \Lambda^\psi(\Lambda^w - 1)}{\kappa_D(\Lambda^\psi - 1)}\right)^v, \quad \text{and} \quad \theta_{U,\tau^s_D} = \frac{1}{v} + \left(\theta_{U,\tau^s_U} - \frac{1}{v}\right) \Lambda^{-w},$$

where $\theta_{U,\tau^s_j}$ the revenue share allocated to firm $U$ when firm $j$ invests at the stopping time $t = \tau^s_j$.

The sequential investment equilibrium strategies in Proposition 1 provide three main insights. First, the timing of the investments of both firms in equilibrium maximizes joint surplus. Paraphrasing, the optimal thresholds at which firms invest coincide with those that would obtain if a central planner exercised all supply chain growth options optimally. The reason is that, each time upon exercise, it is only one firm that extracts the future growth option value in the supply chain through transfer prices, internalizing joint surplus and leading to an efficient outcome.

The second relevant prediction of Proposition 1 is that the relatively more patient firm $D$ extracts all future value from firm $U$ at the efficient threshold $z^s_U$. The economic intuition behind this result follows from Rubinstein (1982): firm $U$ anticipates that any strategy that does not maximize the value of firm $D$ at $t = \tau^s_U$ would result in rejection, and hence both firms settle at the revenue share $\theta_{U,\tau^s_U}$, without any further delay in investment other that the investment delay that is economically efficient.$^{17}$

$^{17}$As discussed in Dixit and Pindyck (1994), irreversible investment creates option value of waiting to invest. Such delay is economically efficient.
The investment strategies in Proposition 1 also imply that the vertical bargaining power of firm D allows her to extract the growth option value of its own investment opportunity at $t = \tau^*_U$, even before firm U has decided to accept or reject her offer at $t = \tau^*_D$. Both firms agree on a revenue sharing rule $\theta_{U,\tau^*_U}$ such that firm D extracts the value of her own investment $t = \tau^*_D$ by making firm U pay for it in advance. This, in turn, is incentive compatible: it forces firm U to accept the offer from firm D at $t = \tau^*_D$ to avoid losses.

Last, the investment strategies in Proposition 1 are such firm U is worth the preinvestment value of its assets in place, either before any investment is made, or after all growth options in the supply chain are developed. In contrast, before any investment takes place, firm D is worth the value of its assets in place, plus the growth option value of all investment projects to be undertaken in the supply chain. Anticipating, the way in which supply chain value is allocated across firms over time affects their expected returns.

1.5.2 Joint investment equilibrium

The model admits multiple joint investment or *clustering* equilibria, in which firms invest at a common threshold $z^c$. In what follows, we highlight the main aspects of the clustering equilibria.

First, firm U invests jointly with firm D in equilibrium as long as firm U is worth the preinvestment value of its assets in place. The rationale for this outcome relies on the incentives of both firms U and D to invest jointly. On one hand, for a clustering equilibrium to occur, the value of firm U associated with the sequential investment strategy must be lower or equal than its value under the alternative joint investment strategy so that $V^s_{U,t} \leq V^c_{U,t}$ for any $Z_t$. Otherwise, firm U would invest at the lower investment threshold $z^s_U < z^c$.

On the other hand, for a clustering equilibrium to occur, firm D should be willing to accept the offer of the more impatient firm U at the joint investment threshold $z^c$. Firm D accepts the offer from firm U and simultaneously invests at the threshold $z^c$ if and only if firm D extracts more value under joint investment than under the disagreement outcome, or more value than deviating and investing later on. For this reason, firm D only accepts the offer of firm U in the range $z^c < z^s_D$. As long as $z^c < z^s_D$, firm D extracts all future supply chain value from firm D upon investment.

Last, while the model admits multiple clustering equilibria, the Pareto optimal clustering equilibrium for both firms is to invest at the threshold $z^*_D$, and there exists no alternative clustering
equilibrium threshold lower than \( z_D^{c*} \) so that \( z_D^{c*} \leq z^c < z_D^s \). While firm D extracts all future supply chain value in any clustering threshold \( z^c \), investing jointly at the threshold \( z_D^{c*} \) maximizes joint profits, conditional on firms investing simultaneously in equilibrium. Intuitively, since firm D extracts all future value in equilibrium, it is optimal to do so without delay.

In sum, the derivation of the clustering equilibria of the model relies on the premise that a joint investment strategy \( z^c \) is sustainable as long as firm U is worth the preinvestment value of its assets in place. Moreover, if firm D extracts all future supply chain value upon joint investment, it must be the case that \( z^c < z_D^s \). If firm D is worth the preinvestment value of its assets in place in all equilibria, we predict a range of clustering equilibrium thresholds so that \( z_D^{c*} \leq z^c < z_D^s \). The value of both firms is weakly higher under the joint investment threshold \( z_D^{c*} \).

**Proposition 2** (Clustering equilibrium strategies) The subgame-perfect clustering equilibria in a bilateral monopoly with firms \( j = U, D \) and \( \kappa_U < \kappa_D \) is so that firms invest simultaneously at the threshold \( z^c \in [z_D^{c*}, z_D^s] \). While there is a continuum of equilibrium thresholds over this interval, the Pareto optimal equilibrium threshold \( z_D^{c*} \) is given by

\[
z_D^{c*} = \frac{(\kappa_U + \kappa_D)K}{\Omega(\Lambda^{\psi+\omega} - 1)} K^{\psi+\omega} \frac{\delta v}{v - 1},
\]

and the corresponding sharing rule \( \theta_{U, c^c} \) is given by

\[
\theta_{U, c^c} = \frac{\kappa_U(v - 1)}{v(\kappa_D + \kappa_U)} + \frac{(\kappa_D v - \kappa_U(v - 2))}{2v(\kappa_D + \kappa_U)\Lambda^{\omega+\psi}}.
\]

As we elaborate in the Appendix, the Pareto optimal clustering investment strategy described in Proposition 2 is computed in a similar fashion as the optimal investment thresholds in the sequential investment case. Since firm U is relatively more impatient and hence has less bargaining power, the revenue share \( \theta_{U, c^c} \) ensures that firm U is worth the preinvestment value of its assets in place at the threshold \( z_D^{c*} \). Firm U chooses the threshold \( z_D^{c*} \) so as to maximize the value of firm D: any other offer would result in rejection.

**1.5.3 Equilibrium refinement.**

Fudenberg and Tirole (1985) argue that if one equilibrium Pareto dominates all others, it is them
most reasonable outcome to expect. We apply an equilibrium refinement to determine when firms invest simultaneously or sequentially in equilibrium. Out of all the joint investment equilibria of the model, we focus on the Pareto optimal clustering equilibrium.

**Proposition 3** (Pareto Dominance Refinement) In a bilateral monopoly with $\kappa_U < \kappa_D$, it holds that $V_{Du}^s > V_{Du}^{c\ast}$ and $V_{Uu}^s = V_{Uu}^{c\ast}$ at $t = \tau_U^s$ for any $\sigma_\kappa$. Hence firm $D$ opts for the leader investment strategy at $t = \tau_U^s$ in equilibrium.

Proposition 3 contains several predictions. The first is that, if we consider a Pareto-dominance refinement, it is firm $D$ the one that ultimately decides on the equilibrium outcome. Intuitively, since firm $D$ is relatively more patient than firm $U$ in exercising its growth options, it only accepts the offer of firm $U$ at $t = \tau_U^s$ if this offer is more convenient than the offer of firm $D$ at $t = \tau_D^c$.

The second prediction in Proposition 3 is that the value of firm $D$ is weakly higher in the sequential investment equilibrium. The rationale for this result relies on two main arguments. The first argument is that, when firms have different investment costs $\sigma_\kappa$, firms maximize joint value by investing sequentially. As explained in Weeds (2002) and Pawlina and Kort (2006), when firms invest so that joint surplus is maximized, joint investment embeds inefficient investment delay for one of the two projects. The second argument, which is specific to our model, relies on the timing at which firm $D$ extracts the supply chain future value in both equilibria. In the sequential investment equilibrium, firm $D$ extracts the growth option value of the supply chain already at $t = \tau_D^s$. In the clustering equilibrium, this happens later in time at $\tau_D^{c\ast} > \tau_U^s$.

In sum, the model shows that, due to its higher bargaining power and regardless of the equilibrium outcome, firm $D$ always leaves firm $U$ no value beyond that of its assets in place before any investment takes place. Firm $D$ extracts the value added of all growth options in the supply chain pair through incentive compatible revenue sharing offers. Moreover, firm $D$ strictly prefers the sequential investment equilibrium, so as to exercise all growth options in the supply chain earlier rather than later.

### 1.5.4 Comparative Statics

We illustrate the properties of the equilibrium outcomes in Propositions 1 and 2 by considering the comparative statics of firms’ investment strategies with respect to the underlying parameters $\kappa_D$,
Consider first the comparative statics with respect to $\kappa_D$, which implicitly refer to how an increase in the heterogeneity in firms’ production technologies $\sigma_\kappa$ affects firms’ investment strategies in equilibrium. Figure 1 illustrates firms’ investment strategies and their values in the sequential investment equilibrium. The top left chart shows that the investment threshold $z^*_D$ is increasing in $\kappa_D$: intuitively, it is efficient to delay investment as it becomes more costly. The top right chart shows that the revenue shares of firm $U$ are increasing in $\kappa_D$. As $\kappa_D$ increases, the exercise of the investment of firm $D$ is done later in time so that the expected value of total supply chain growth options is lower, and hence firm $U$ requires a higher revenue share to ensure it is worth the preinvestment value of its assets in place. The bottom left chart in Figure 1 compares the values of firms $U$ and $D$ under sequential investment. The value of firm $U$ is the same regardless of the level of $\kappa_D$. In contrast, firm $D$ acquires all the growth option value of firm $U$ as a result of bargaining.

Figure 2 illustrates firms’ investment strategies and their values as a function of $\kappa_D$, when firms invest jointly in equilibrium. The top left chart compares the Pareto optimal clustering threshold $z^{**}$ with the threshold $z^*_D$ that acts an an upper bound to all possible values of $z^c$. The Pareto optimal clustering threshold allows firm $D$ to extract supply chain value sooner rather than later. The top right chart shows that the revenue share of firm $U$ is higher in the case in which firms invest at $z^{**}$. The revenue share of firm $U$ is also decreasing in $\kappa_D$: this is the result of coordination. The bottom left chart in Figure 2 shows that the value of firm $D$ is the same regardless of the level of $\kappa_D$. Moreover, the value of firm $D$ in Figure 2 is always strictly lower with its analog in Figure 1 –under sequential investment.

Figure 3 illustrates the comparative statics of firms’ investment strategies and revenue shares with respect to the parameters $\sigma_Y$, $\alpha_D$ and $\varepsilon$. A novel aspect of the model is to contribute to the literature of strategic bargaining by modeling the underlying determinants of firms’ bargaining power. The comparative statics with respect to $\sigma_Y$, $\alpha_D$ and $\varepsilon$ show how the elasticity of demand downstream, market uncertainty and firms’ overlap in the supply chain pair affect their revenue shares in equilibrium. Given the refinement in Proposition 3, we focus on the sequential investment equilibrium for brevity.

Consider first the comparative statics of the model with respect to $\sigma_Y$. The parameter $\sigma_Y$ captures the risk loading on the systematic exposure of demand shocks downstream. Investment
thresholds increase as $\sigma_Y$ increases. This is consistent with the stylized predictions of the real options literature: as $\sigma_Y$ increases, so does the option value of waiting to invest (Dixit and Pindyck, 1994). The effect of $\sigma_Y$ on firms’ revenue shares depends on the timing of the investment decision. At $\tau_D^*$, a higher level of $\sigma_Y$ leads to higher growth option value, and hence a lower revenue share $\theta^*_U$ so that firm $U$ meets its participation constraint. At $\tau_U^*$, the revenue share of firm $U$ is almost insensitive to $\sigma_Y$: by construction, firm $U$ is always worth the preinvestment value of its assets in place at $\tau_U^*$.

Consider the comparative statics with respect to $\alpha_D$. In the model, the parameter $\alpha_D$ partially determines the share of revenues that firm $D$ allocates to cover for the inputs of production purchased to firm $U$. The parameter $\alpha_D$ also captures how relevant firm $U$ is for firm $D$ in its production process: if $\alpha_D$ is relatively large, then the production of firm $U$ is pivotal for the development of firm $D$. Figure 3 shows that revenue shares are increasing in $\alpha_D$: if the inputs of firm $U$ are more relevant for the production process of firm $D$, the revenue share allocated to firm $U$ increases. Moreover, when firm $U$ is about to invest, it significantly accelerates investment as $\alpha_D$ increases; this is because its relative bargaining power is enhanced.

Last, consider the comparative statics with respect to the downstream elasticity of demand $\varepsilon$. Since firm $D$ is a monopolist in its own product market, the parameter $\varepsilon$ captures the market power of firm $D$. As market power downstream increases, Figure 3 shows that the revenue share of firm $U$ decreases: since firm $D$ captures all the growth option value of the supply chain pair, higher elasticity of demand downstream boosts its revenues. Moreover, since the diffusion of the supply chain shock $\sigma_Z$ is increasing in $\varepsilon$, firms’ optimally delay their investments as $\sigma_Z$ increases. Paraphrasing, the market power of firm $D$ leads to efficient investment delay.

As a final remark, we note that in the model higher market power downstream is weakly beneficial for both customers and suppliers. In the model, higher market power boosts total growth option value in the supply chain; this need not mean that such value gets allocated to firm $D$. While Figure 3 shows that higher $\varepsilon$ leads to higher revenue shares for firm $D$, this is solely because firm $D$ is also the firm with the higher investment cost $\kappa_U < \kappa_D$. Higher market power downstream is instead more beneficial for firm $U$ in the alternative case in which $\kappa_U > \kappa_D$.

\footnote{See Appendix for further details on this result.}
1.6 Asset Pricing Implications

1.6.1 Vertical Bargaining Power and Asset Prices

The model predicts an unconditionally positive relation between a firm’s exposure to systematic risk or earnings-to-price ratios before investment, and its revenue shares upon investment.

**Corollary 1** [Revenue Shares in Equilibrium] For any any $Z_t < z^*_U$, firms’ with higher vertical bargaining power (and hence higher $\kappa_j$) have lower earnings-to-price ratios and higher expected returns. A firm’s expected return $R_{jt}$ (resp. earnings-to-price ratio $\chi_{jt}$) before investment is strictly increasing (resp. decreasing) in its revenue share upon investment.

Corollary 1 provides two main insights. First, before negotiations take place, the vertical bargaining power of any firm $j$ is captured in its earnings-to-price ratio. For any investment strategy $z_j$ in equilibrium, a relatively lower earnings to price ratio indicates that firm $j$ has higher vertical bargaining power than its peer firm $-j$. Since firms’ betas are a decreasing function of their earnings-to-price ratios, firms with higher vertical bargaining power are also riskier.

Figure 1 illustrates the predictions of Corollary 1 for firms’ betas in the sequential investment equilibrium. As $\kappa_D$ increases, so does the relative bargaining power of firm $D$. The bottom right panel of Figure 1 then compares firms’ betas before investment as a function of $\kappa_D$. The preinvestment beta of firm $D$ is always strictly higher than that of firm $U$. Moreover, while the preinvestment beta of firm $D$ is increasing in $\kappa_D$, that of firm $U$ remains constant and equal to the riskiness of its assets in place.

Corollary 1 also states that a firm’s revenue share upon investment reflects its relative vertical bargaining power at the time of the most recent negotiation with its supply chain peer. Hence there exists a strictly negative relation between a firm’s earnings-to-price ratio before investment and its revenue share upon investment. Since a firm’s expected return is strictly decreasing in its earnings-to-price ratio, a firm’s expected return before investment relates positively with its revenue share upon investment. This prediction is also illustrated in Figure 1.
1.6.2 Vertical Bargaining Power and Risk Dynamics

The model characterizes the dynamics of expected returns and firms’ earnings-to-price ratios in equilibrium as a function of the intra supply chain dispersion in technologies $\sigma_\kappa$.

**Corollary 2** *(Expected Return and Earnings-to-Price Dynamics)* Given Assumption 1 and Propositions 1-3, there exists negative comovement in firms’ expected returns $R_{jt}$, and such comovement becomes more negative as $\sigma_\kappa$ increases. Moreover, since firms’ expected returns $R_{jt}$ are a linear decreasing function of firms’ earnings-to-price ratios $\chi_{jt}$, the same dynamics apply to firms’ earnings-to-price ratios in equilibrium.

Corollary 2 states that the comovement in the expected returns and earnings-to-price ratios of firms $U$ and $D$ is negative. To understand this prediction, consider first the stage in which firm $U$ is about to invest. Firm $U$ expects a reduction in its revenue share upon bargaining with firm $D$ at $t = \tau_{U}^s$. The earnings-to-price ratio of firm $U$ increases as the growth option of firm $U$ becomes more in the money, and its expected return increases. At the same time, firm $D$ expects an increase in its revenue share, so that its earnings-to-price ratio decreases and its expected return increases before the stopping time $t = \tau_{U}^s$. Figure 4 illustrates the corresponding dynamics of firms’ risk loadings $\beta_{jt}$ in equilibrium. We observe negative comovement between $\beta_{Ut}$ and $\beta_{Dt}$ when firm $U$ is about to invest.

Consider now the stage in which firm $D$ is about to invest. In this case, there is no comovement between $\beta_{Ut}$ and $\beta_{Dt}$. Figure 4 illustrates the corresponding dynamics. While the value of firm $U$ is expected to increase upon investment and hence its expected return rises as $Z_t$ approaches $z_D^s$, the expected return of firm $D$ is constant during this stage. Due to firms’ revenue shares in equilibrium, the value of firm $D$ is worth the value of its assets in place before and after its own investment. We conclude that the average negative comovement in the expected returns of firms $U$ and $D$ is driven by the dynamics of firms’ expected returns at $t = \tau_{U}^s$.

Corollary 2 also mentions that the negative comovement in expected returns is increasing in the standard deviation in firms’ vertical bargaining power captured by $\sigma_\kappa$. Intuitively, at $t = \tau_{U}^s$, firm $D$ not only extracts the future rents of the growth option of firm $U$, but also makes firm $U$ pay in advance for the value of the future rents of the growth option of firm $D$, to be realized upon investment after $t = \tau_{D}^s$. As $\sigma_\kappa$ increases, the rent extraction mechanism by which firm $U$ pays
in advance for the growth option value of firm $D$ leads to higher dispersion in revenue shares, and hence more negative comovement in expected returns.$^{19}$

1.6.3 Supply Chain Risk Loadings

Corollaries 1 – 2 yield predictions that apply to the cross sectional variation in asset prices within a given supply chain pair. The model also provides comparative statics on how the risk loadings on firms’ assets in place and growth opportunities vary across different supply chain connections. Aspects such as the elasticity of demand downstream or the volatility of supply chain shocks are key in explaining variation in risk loadings across supply chain pairs.

Equation (4) shows that the risk loading of assets in place due to variation in the supply chain shock $Z_t$ is given by $\sigma_Z$, whereas the corresponding risk loading for growth opportunities equals $\upsilon\sigma_Z$. Since Lemma 1 shows that the state variable $Z_t$ is itself endogenously determined, the model characterizes how firms’ production technologies and market power affect risk loadings. We elaborate on these predictions by means of Figure 5. The figure focuses the comparative statics of $\upsilon\sigma_Z$ and $\upsilon$ to illustrate how $\sigma_Z$ and $\upsilon$ contribute to explaining changes in the risk loading of growth opportunities. The comparative statics on the risk loading of assets in place $\sigma_Z$ are inferred. We focus on the parameters $\varepsilon$, $\sigma_Y$ and $\alpha_D$ for the sake of brevity.

The top panels of Figure 5 show that an increase in the elasticity of demand $\varepsilon$ or market power downstream leads to an increase in the risk loading of both the assets in place and growth opportunities of firms in the supply chain pair. The middle panels of Figure 5 show that an increase in the diffusion of demand shocks $\sigma_Y$ also increases the risk loading of both assets in place as growth opportunities. Last, the bottom panels of Figure 5 show that an increase in the input intensity of firms downstream $\alpha_D$ leads to a higher risk loading in both assets in place and growth opportunities. Intuitively, as the profits and costs of suppliers and customers have a higher overlap, the risk loading linked to supply chain shocks $Z$ also increases.

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$^{19}$ In the example of Figure 4, the correlation between the expected returns of firms $U$ and $D$ equals $\approx -0.5$ with $\kappa_U = 1$ and $\kappa_D = 5$. In the alternative case in which $\kappa_U = 1$ and $\kappa_D = 7$, the correlation equals $\approx -0.65$. 

25
2 Extended Model

The basic model in the previous section assumes that firms $U$ and $D$ have a single source of revenue that relates to the supply chain in which they are engaged. In practice, however, this is rare: firms have multiple sources of revenue as they may sell multiple products or operate in multiple segments. We hereby study how these additional sources of income affect the predictions of the basic model.

2.1 Operating profits with multiple business segments

We enrich the set of assumptions in the basic model by assuming that firm $j$ has an additional source of income equal to $\gamma_j K_j \Omega (U_t) + \omega$. Firms’ total operating profits, considering all business segments, equal $\Pi_j [Y_t, z_t] \equiv Y_t \times \pi_j [Z_t]$. The function $\pi_j [Z_t]$ is defined as

$$\pi_j [Z_t] \equiv (1 - \gamma_j) \times Z_t \times \theta_j \Omega (U_t) \Omega (D_t) + \gamma_j \times K_j \Omega (U_t),$$

(10)

and the parameter $\gamma_j \in (0, 1)$ in Equation (10) captures the relative contribution of the alternative business segment of firm $j$ to its total operating profits.

We further assume that while firm $j$ has the option to increase the installed capacity of the business segment in which it bargains with firm $-j$ by $\Lambda_j > 1$, the installed capacity allocated to the alternative business segment equals $\gamma_j K_j \Omega (U_t)$. As we elaborate below, this implies that firm $j$ may use revenues from alternative business segments to fund investment in the segment in which it bargains with firm $-j$. Firms’ incentives to use their internal capital market to fund growth opportunities in the segment in which they bargain diminish as $\gamma_j$ increases.

2.2 Sources of Bargaining Power

The basic model suggests that a firm’s comparative advantage depends on its investment cost $\kappa_j$ or its initial installed capacity $K_j \Omega (U_t)$. Firms with lower initial scale of production or lower investment costs are more impatient to invest, and hence more willing to forgo future expected value while bargaining with their supply chain peer. In the extended mode, a firm’s comparative advantage also depends on the parameter $\gamma_j$. As we prove in the Appendix, when firms’ vertical bargaining power solely depends on the relative importance of alternative sources of income captured by $\gamma_j$, 

the corresponding sorting condition is given by
\[ \frac{\partial}{\partial \gamma_j} \left( \frac{\partial V_{jt}}{\partial z_j} \right) > 0. \]  
(11)

Intuitively, firms are relatively more impatient to invest when the business segment in which their bargain represents a larger fraction of their total operating profits.

The parameter \( \gamma_j \) has two relevant effects in extended model. First, differences in \( \gamma_j \) across firms affect their incentives to invest earlier than their peer. This is captured by the sorting condition in Equation (11). If firm \( U \) has a lower fraction of income from other segments such that \( \gamma_U < \gamma_D \), then firm \( U \) is relatively more impatient to invest in the segment in which both firms bargain, so that firm \( D \) has relatively higher vertical bargaining power.

The second effect of \( \gamma_j \) on the equilibrium outcome relates to its effect on firms’ reservation values. Firms’ ability to generate revenues in multiple segments modifies their disagreement outcome. Consistent with Binmore et al. (1986), and all else equal, \( \gamma_j > 0 \) creates differences in the reservation value of each firm \( j \) in case of no agreement. Upon rejection, firms stay with the value of their assets in place, which in the basic model is solely driven by the same line of business that they shared with their peer. The additional source of income leads to differences in firms’ reservation values in case of disagreement, and hence to differences in both investment timing and revenue shares in equilibrium.

### 2.3 Operating Hedge and Asset Prices

Given that firms’ expected returns are a linear function of a firm’s risk loading or beta, we solve for the functional form of the systematic risk loading \( \beta_j [Z_t] \) in the presence of multiple business segments. The corresponding expression is given by
\[ \beta_j [Z_t] = \sigma_Y + \sigma_Z (1 - \iota \times h [Z_t]) \frac{X_j [Z_t]}{\delta} + \sigma_Z v \times \left( 1 - \frac{X_j [Z_t]}{\delta} \right) \]  
(12)

where the parameter \( \iota > 1 \) is defined in the Appendix, and we define \( h [Z_t] \) as the operating hedge of the firm. In an analogy with the literature on fixed costs and operating leverage (Gahlon and
Gentry (1982), Donangelo (2014)), we denote a firm’s operating hedge by

\[ h_j[Z_t] \equiv \frac{\gamma_j K_{0j} Y_t}{\Pi_{jt} [Y_t, Z_t]} < 1, \tag{13} \]

where the function \( h[Z_t] \) captures the local sensitivity of operating profit growth to supply chain shocks \( Z_t \). The level of operating hedge of each firm \( j \) equals the scaled slope of a regression of operating profit growth on the exogenous shocks that affect total revenues.

Equation (12) shows that a firm’s risk loading in the extended model is a function of both its earnings-to-price ratio and its operating hedge. The first term captures the exposure to systematic risk associated with the demand shock \( Y_t \). The second term captures the exposure to systematic risk of the assets in place due to variation in the supply chain shock \( Z_t \), which is attenuated by the operating hedge of the firm. The third term captures the exposure to systematic risk of growth opportunities due to variation in \( Z_t \).

### 2.4 Equilibrium Outcome

The derivation of the equilibrium outcome follows the same steps as that of the basic model. Two alternative parameter configurations are relevant to illustrate the predictions of the extension with multiple business segments. The first configuration assumes that all firms have the same investment costs and initial installed capacities, and instead firms differ in the fraction of income from other business segments so that \( \gamma_U < \gamma_D \). Figure 6 illustrates the corresponding equilibrium strategies. Consistent with the sorting condition in Equation (11), the relatively more patient firm \( D \) (with less skin in the game in the segment in which it bargains) extracts all future supply chain value from its peer in equilibrium.

We also solve for the equilibrium outcome in the extended model for the alternative case in which firms have the same fraction of income in other business segments before investment so that \( \gamma_j \equiv \gamma \), and instead they differ in their investment costs as stated in Assumption 1. The qualitative predictions on investment strategies in this case are the same as in Section 1.

Figure 7 illustrates the dynamics for firms’ expected returns and operating hedge in the extended model. To better compare our results with those in Section 1, we consider the case in which \( \gamma_j \equiv \gamma \) and Assumption 1 holds. We consider a Pareto-dominance equilibrium refinement and focus on the
leader-follower equilibrium. Figure 7 shows that the operating hedge of both firms has a downward trend, since the operating profits in the segment in which both firms bargain increase over time. More importantly, the expected returns of customers and suppliers correlate negatively on average as long as the operating hedge of both firms is moderate.\footnote{As the operating hedge increases, the decreasing trend in the operating hedge leads to positive co-movement the returns of both firms. The decreasing trend in operating leverage, however, is not a general result: the revenues from other sources of income are assumed constant over time for simplicity.} Hence the qualitative predictions of the basic model for the dynamics of expected returns also hold in the extended model, as long as the business segment in which firms bargain remains their core business.

In a recent article, Hackbarth and Johnson (2015) find that changes in operating leverage and earnings-to-price ratios may sometimes lead to opposing effects in firms’ overall exposure to systematic risk. The extended model in this section contributes to this paper by considering instead the effects of a firm’s operating hedge on its exposure to systematic risk. As shown in Figure 7, the operating hedge of firm $D$ reinforces the dynamics of earnings-to-price ratios driving down its expected returns as it exercises its own growth opportunity. In contrast, the dynamics of the operating hedge of firm $U$ and those of its earnings-to-price ratios go in opposite directions when firm $U$ invests. Also, the betas of both firms are higher than firms’ preinvestment betas, once the supply chain matures and both firms have invested. This is because firms’ portfolio of operating revenues becomes less diversified upon investment.

## 3 Empirical Evidence

We begin by summarizing the testable predictions of the model. The main prediction of the theoretical framework is that firms with relatively higher vertical bargaining power have relatively higher returns. The model suggests we can capture vertical bargaining power both through firms’ earnings-to-price or book-to-market ratios, and also firms’ revenue shares upon investment. Throughout our analyses, we use book-to-market ratios instead of earnings-to-price ratios as a better proxy for the ratio of a firm’s value of assets in place to its total value.

The basic model also predicts that returns comove more negatively if the spread in bargaining power between customers and suppliers is relatively high. This result holds since firms’ rent seeking behavior is enhanced by more dispersed production technologies. The prediction is still valid when
firms have diversified sales, as long as the revenue associated with the supply chain segment under study is the core driver of firms’ investments. We conjecture lower comovement in expected returns when the customer-supplier spread in revenue shares or book-to-market ratios is higher.

Last, the model shows that the positive relation between returns and bargaining power within a supply chain connection is triggered by firms’ investment opportunities. Firms with higher returns today have higher market to book ratios, as they extract all the future expected value of the investment opportunities in the supply chain. We thus conjecture a positive relation between investment rates and book-to-market ratios, and a positive relation between investment rates and revenue shares within a supply chain connection. Intuitively, we should observe higher investment rates in those firms that benefit the most from supply chain growth.

3.1 Data Sources and Sample Construction

Our working sample blends data from multiple sources. We use Compustat for firm fundamental data at annual frequency, and CRSP data at monthly frequency for stock returns. We also use data from the Bureau of Economic Analysis (BEA) to create the classification between customers and suppliers, and calculate measures of relative division of gains between customers and suppliers. Since our method of classification is at the industry level, we test all predictions of the model on inter-industry supply chain pairs. The BEA provides Input-Output (IO) tables summarizing the production and consumption of commodities by U.S. industries. Since the BEA data starts in 1997, we begin our sample as of January 1997. We do not use data prior to January 1997 to ensure the structure of the supply chain remains stable throughout our sample.

We use the information of the IO tables to construct supplier-customer industry pairs. Each customer-supplier pair in the sample is unique: for a given combination of industries, we construct the sample so that there is always one industry that is primarily a customer, and another industry that acts primarily as a supplier. The same industry may appear in multiple pairs. We consider the IO tables reported by the BEA in year 2007 throughout our analysis. The IO tables of 2007 (containing 389 industries) are the most granular IO tables available to date, in terms of both number of industries and commodities surveyed. In untabulated tests, we find that the structure

\[21\] For those supply chain pairs in which we find more than one correspondence for the same pair of industries, we consider the net trade between both industries to select a customer and a supplier.
of the U.S. supply chain has remained stable over the years 1997 to 2016.\footnote{Less granular IO tables with 71 industries are calculated yearly between 1997 and 2016 by the BEA. In unabulated tests, using 71-industry tables, we find that the structure of the U.S. production network remains stable between 1997 and 2016.}

Following Ahern (2012), for each IO industry pair we construct variables capturing the importance of a supplier’s industry output for a customer’s industry output and vice versa. We denote these measures by $\text{ImpU}$ and $\text{ImpD}$, respectively, and calculate them as follows:

$$
\text{ImpU} \equiv \frac{\text{\$ Supplier Input}}{\text{Total \$ Customer Output}}, \quad \text{and} \quad \text{ImpD} \equiv \frac{\text{\$ Customer’s Purchases}}{\text{Total \$ Supplier’s Sales}}.
$$

The variable $\text{ImpU}$ represents the dollar value of the supplier industry’s output required to produce one dollar of the customer industry’s output. Through the lens of the model, $\text{ImpU}$ is a function of the input intensity downstream captured by $\alpha_D$, and the revenue share of firms downstream $(1 - \theta_{U,r})$. A higher value of $\text{ImpU}$ implies that the supplier industry $U$ has more bargaining power in the negotiations with industry $D$, since the technology of the customer industry $D$ relies more heavily on their production. Similarly, a higher value of $\text{ImpU}$ implies that the supplier industry $U$ has more bargaining power, so that the revenue share of the customer industry $D$ is relatively low.

The variable $\text{ImpD}$ is equal to the ratio of a customer industry’s purchases from a given supplier industry relative to the total sales of such supplier industry. A higher value of $\text{ImpD}$ implies that the customer $D$ has more bargaining power in the negotiations with industry $U$, since the sales of its supplier are less diversified. Through the lens of the model, $\text{ImpU}$ is a function of the fraction of operating profits downstream in the same segment as firms upstream or $(1 - \gamma_D)$. Since $\text{ImpD}$ is at the industry level, it captures firms’ ability to sell in multiple segments or industries (as opposed to firms in the same industry), as discussed in Section 2.

Given the definitions of $\text{ImpU}$ and $\text{ImpD}$, it follows that the relative bargaining power of an industry downstream with respect to an industry upstream is captured by the ratio of $\text{ImpD}$ over $\text{ImpU}$. When the ratio of $\text{ImpD}$ over $\text{ImpU}$ is low, the bargaining power downstream is low in the negotiations with the upstream industry. Conversely, when the ratio is ratio of $\text{ImpD}$ over $\text{ImpU}$ high, the bargaining power downstream is high in the negotiations with the upstream industry. Through the lens of the model, the ratio of $\text{ImpD}$ over $\text{ImpU}$ is increasing in the spread between
\( \gamma_U \) and \( \gamma_D \), and also depends on the difference between \( \kappa_U \) and \( \kappa_D \) determining firms’ revenue shares in equilibrium.

### 3.2 Summary Statistics

Table 1 provides the summary statistics of our working sample. The unit of observation consists of a customer-supplier pair, where customers are suppliers are defined at the industry level. There are 63,827 customer supplier industry pairs, over a span of 21 years, between 1997 and 2017.

Table 1 reports the summary statistics for realized equity returns in our working sample. For each supply chain pair, we consider both the equity returns of firms of suppliers \( RetU \) and customers \( RetD \). We also construct a variable capturing the difference between \( RetD \) and \( RetU \) within a given supply chain pair, which we refer to as \( DifRetU \). For the median supply-chain pair, the difference between the realized returns of customers and suppliers is not statistically different from zero. Since all variables in Table 1 are at annual frequency, we report annualized returns. We use returns at monthly frequency for the tests on intra supply chain comovement.

Table 1 reports the summary statistics on book to market ratios and investment-to-capital ratios for each supply chain pair in our sample. For the median supply chain pair, the difference between \( BtmD \) and \( BtomU \) labeled as \( DifBtmU \) is negative. This suggests that downstream firms have lower book to market ratios, and hence higher growth opportunities. In contrast, for the median supply chain pair, the difference between the investment-to-capital ratios \( InvD \) and \( InvU \) is negative, suggesting that industries upstream invest more than industries downstream. These two alternative observations are not inconsistent, insofar relative adjustment costs may vary for each supply-chain pair, and firms differ in their leverage structure. For the median supply-chain pair in our sample, industries downstream have lower book leverage than industries upstream.

Last, Table 1 reports the summary statistics related to the variables \( ImpU \) and \( ImpD \), capturing firms’ bargaining power within the supply chain. Each of the measures is multiplied by 100 and hence already expressed in percentages. For the median supply-pair in our sample, the relative importance of suppliers or \( ImpU \) is 0.02%, and that of customers or \( ImpD \) is similar. The means reported in Table 1 indicate that the measures \( ImpU \) and \( ImpD \) are positively skewed: suppliers’ inputs represents on average 0.2% of customers’ output, while a customers’ purchases represent
0.28% of suppliers’ sales.\textsuperscript{23}

### 3.3 Returns and Vertical Bargaining Power

Consider first the predictions of the model relating expected returns to our measures of bargaining power. Corollary 1 predicts a mechanical relation between a firms’ bargaining power and its book to market ratio. The corresponding testable implication is that $\text{DifRetD}$ is positively related to $\text{BtomD}$ and negatively related to $\text{BtmU}$. The extended model predicts that a firm’s bargaining power is higher when its sales are relatively more diversified. This implies that $\text{DifRetD}$ is positively related to $\text{ImpD}$. Last, Corollary 1 states that the firm with the highest relative return before investment is the firm with the highest relative revenue share upon investment. In line with our earlier discussion on $\text{ImpU}$ in this section, we thus predict a negative relation between $\text{DifRetD}$ and $\text{ImpU}$.

As a caveat, while the model predicts a positive relation between expected returns today and future revenue shares upon investment, our measures $\text{ImpU}$ and $\text{ImpD}$ are entirely cross sectional and assumed constant throughout our sample. We mitigate this concern in two alternative ways. First, while revenue shares at the firm level may change considerably over time, in untabulated results using less granular BEA tables, we observe that revenue shares at the industry level are very stable over time.\textsuperscript{24} Second, we ensure our empirical tests are entirely cross sectional by running Fama-MacBeth regressions for each year in our sample.

Specifications (I) and (II) in Table 2 present Fama-MacBeth regressions of the form

$$\text{DifRetD}_{it} = c_0,t + c_{1,t}\text{Measure}_{Uit} + c_{2,t}\text{Measure}_{Dit} + \epsilon_{it}$$

where the variable Measure$_j$ captures bargaining power of industry $j$ in the supply chain pair $i$. Measure equals $\text{Imp}$ in Specification (I), and equals $\text{Btm}$ in Specification (II). The table reports normalized beta coefficients in parentheses to assess the economic significance of each of the measures of bargaining power.

The evidence in Table 2 is consistent with the predictions of the model. Specification (I) shows

\textsuperscript{23}As a reference, both Fan and Goyal (2006) and Kedia et al. (2011) suggest that a 1% threshold is adequate to identify important vertical relationships between industries which may lead to mergers. This criterion applies to the top 5% of the observations in our working sample. In untabulated results, we find qualitatively similar results if we restrict the sample to such subset of supply chain industry pairs.

\textsuperscript{24}The study by Ahern (2012) makes a similar argument while considering a single cross section of his bargaining measures to explain cross sectional variation in merger returns in a panel dataset.
that the return of industries downstream in excess of that of industries upstream or \textit{DifRetD} is negatively related to the bargaining power of the industry upstream \textit{ImpU}. It is also positively related to the bargaining power of the industry upstream \textit{ImpD}. The absolute magnitude of the normalized beta coefficients is very similar for both measures. With every increase of one standard deviation in \textit{ImpU} (resp. \textit{ImpD}), downstream returns in excess of upstream returns decrease (resp. increase) by \( \approx 0.01 \) standard deviations.

Specification (II) uses book-to-market ratios instead of relative importance shares to explain \textit{DifRetD}. \textit{DifRetD} is significantly higher when firms downstream have low book-to-market ratios. \textit{DifRetD} is also significantly positively related with the book-to-market ratios of firms upstream. Through the lens of the model, these findings suggest that downstream returns are higher when downstream firms absorb the future expected value of the growth opportunities in the supply chain. The normalized beta coefficients are larger in magnitude than those observed for the measures in Specification (I). With every increase of one standard deviation in \textit{BtmU} (resp. \textit{BtmD}), downstream returns in excess of upstream returns increase (resp. decrease) by \( \approx 0.2 \) standard deviations.

Table 2 reports additional specifications as robustness checks. Specification (III) considers all dependent variables in Specifications (I)-(II). Results show that all dependent variables capture relevant variation in the intra-supply-chain cross section in returns. Specification (IV) adds the product of \textit{ImpjxBtomj} for \( j = U, D \) as dependent variables. Last, Specification (V) includes leverage ratios both upstream and downstream as controls. Note that while the predictions of the model refer to asset returns, all industries in our dataset show positive leverage. Controlling for financial leverage, our measures of bargaining power remain significant in explaining \textit{DifRetD}.

### 3.4 Return Dynamics and Vertical Bargaining Power

Corollary 2 in the basic model states that firms’ expected returns comove more negatively if the intra-supply-chain differences in bargaining power are higher. The result prevails once allow firms to have multiple sources of revenue, as long as the segment in which firms bargain remains the core business segment of both industries. To test this prediction, we construct a variable capturing the intra-supply-chain cross sectional variation in bargaining power, which we denote by \textit{VarImp}.

For each supply chain pair \( i \), we denote the variance of firms’ bargaining shares \( \theta_U \) and \( \theta_D \) by \textit{Var}\( \theta \). Assuming that bargaining is efficient such that \( \theta_U = 1 - \theta_D \), we express \textit{Var}\( \theta \) as a function
of $\theta_D$ to obtain

$$\text{Var} \theta_i = \theta_D^2 - \theta_D + \frac{1}{4}.$$  \hspace{1cm} (14)

As mentioned earlier in this section, neither $\text{Imp}_U$ nor $\text{Imp}_D$ as standalone measures capture the relative bargaining power of firm $j$ with respect to firm $-j$ in the supply chain connection: it is the ratio of both that matters. For this reason, we construct the variable $\text{RelImp}_D$ defined as

$$\text{RelImp}_D \equiv \frac{\text{Imp}_D}{\text{Imp}_D + \text{Imp}_U} \approx \theta_D$$

as proxy for $\theta_D$, for each supply-chain industry pair in our sample. $\text{RelImp}_D$ captures the ratio between $\text{Imp}_D$ and $\text{Imp}_U$, while ensuring that $\text{RelImp}_D$ ranges between zero and one, as assumed in the derivation of Equation (14). We replace $\theta_D$ by $\text{RelImp}_D$ in Equation (14) to obtain a proxy of the customer-supplier spread in bargaining power which we denote by $\text{VarImp}_D$. As a robustness check, we construct an additional measure of the cross sectional standard deviation of book-to-market ratios by supply chain pair. We refer to this measure as $\text{VarBtm}$.

To test Corollary 2, we sort all supply-chain pairs into terciles of the measures $\text{VarImp}_D$ and $\text{VarBtm}$. For each subsample, we run regressions of the form

$$\text{Ret}_{D,it} = c_0 + c_1 \text{Ret}_{U,it} + c_{2,t} + c_{3,i} + \epsilon_{it}$$

using data at monthly frequency. We do not use Fama MacBeth Regressions as we do not use $\text{Imp}_D$ or $\text{Imp}_U$ directly. We run instead a panel regression with time fixed effects $c_{2,t}$, and supply chain pair fixed effects $c_{3,i}$. We conjecture that the the coefficient $c_1$ is strictly lower in those terciles in which $\text{VarImp}_D$ and $\text{VarBtm}$ are relatively higher.

Table 3 reports the results of our empirical analyses. Panel A presents the results using $\text{VarImp}_D$ as the sorting variable. Consistent with our conjecture, the coefficient $c_1$ is highly significant in all subsamples, and it decreases significantly as $\text{VarImp}_D$ increases. Comparing the lowest tercile of $\text{VarImp}_D$ with its highest, the normalized beta coefficient decreases by 10%. As a remark, note that the model also predicts that the overall sign of the coefficients in Table 3 should be negative, which is not what we observe. However, to the extent that firms are subject to multiple sources of systematic risk on which their supply chain connection need not load entirely,
this is not a concern. Panel B presents our findings using $VarBtm$ as the sorting variable, with a similar inference. We conclude that the comovement in returns between customers are suppliers is lower when the spread in bargaining power is higher.

### 3.5 Investment and Vertical Bargaining Power

The model highlights a specific economic mechanism triggering the positive relation between returns and firms’ vertical bargaining power. The mechanism relates to firms’ ability to invest. To evaluate whether the empirical evidence is consistent with this channel, we study whether firms with relatively more vertical bargaining power not only have lower book-to-market ratios, but also higher investment-to-capital ratios.

We run Fama-MacBeth regressions with the same specifications as in those Table 2, with $DifInvD$ as the dependent variable. $DifInvD$ captures the within-supply-chain difference in investment to capital ratios at any point in time. Table 4 summarizes the corresponding empirical findings. The evidence is consistent with the conjecture that firms’ bargaining power relates to their growth opportunities, and hence to their ability to invest. Specification (I) shows that $DifInvD$ is positively and significantly related to $ImpD$ or bargaining power downstream. Specification (II) shows that $DifInvD$ is significantly higher when firms downstream have low book-to-market ratios, and significantly lower when firms upstream have high book-to-market ratios. With every increase of one standard deviation in $BtmU$ (resp. $BtmD$), downstream investment in excess of upstream investment increases (resp. decreases) by 0.26 (resp. 0.21) standard deviations.

Specifications (III) to (V) show that the baseline results on investment-to-capital ratios are robust to the inclusion of control variables. In Specification (III), $ImpD$ becomes negative and highly significant. Specification (V) further shows that both $LevU$ and $LevD$ are relevant in explaining $DifInvD$. Note that investment equations are regularly understood in the literature use book-to-market asset ratios, as opposed to book-to-market equity ratios, to explain investment-to-capital ratios. The cross sectional differences in leverage ratios, which account for the difference between book-to-market equity and asset ratios, also explain variation in $DifInvD$. 

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4 Conclusion

This paper provides a real options model of strategic bargaining that endogenizes firms’ revenue shares in customer-supplier relations, and characterizes the relation between firms’ vertical bargaining power and expected returns. The strategic bargaining game shows that relatively larger firms with more diversified sales have higher vertical bargaining power. The model predicts that vertical bargaining power not only makes firms more valuable, but also riskier. The paper also provides empirical evidence in support of the main predictions of the model. Our findings contribute to the growing literature on industrial organization and asset prices, which has primarily focused on horizontal relations across firms in product markets, and has neglected the importance of vertical interactions in explaining cross sectional variation in firms’ values and expected returns.

The broader conclusion that stems from this paper and applies broadly to finance and economics research is that endogenizing firms’ revenue shares in supply chains as the result of bilateral bargaining summarizes in a single measure the industrial organization forces at play in vertical relations, including firms’ production technologies, firms’ outside options, and other aspects such as firms’ demand elasticities and the volatility of their cash flow shocks. We argue that a firm’s revenue share in a customer-supplier relationship captures its current bargaining power, while its book to market ratio relative to that of its supply chain peer captures its future bargaining power. While it is true that bilateral monopolies are rare in the strict sense, Porter (1998) observes that firms behave strategically with buyers and suppliers to preserve their competitive edge. It seems intuitive, then, that the predictions of our model are consistent with the empirical evidence.
References


Appendix

Proof of Lemma 1

Given our assumptions in Section 1, operating profits $\Pi_{jt}$ are given by

$$
\Pi_{Ut} \equiv p_{Ut} \times Q_U [M_{Ut}, K_{Ut}] - cX_t \times M_{Ut},
$$

$$
\Pi_{Dt} \equiv p_{Dt} \times Q_D [M_{Dt}, K_{Dt}] - p_{Ut} \times M_{Dt},
$$

where $p_{Ut}$ is the price of the intermediate good produced by firms upstream, and determined in equilibrium given the demand for inputs of production downstream.

We solve for the equilibrium operating profits of each firm by considering that, in the absence of costs of negotiation, the allocation of profits is efficient. As a result, the input price $p_{Ut}$ is a function of the revenue share $\theta_{U, t}$ such that

$$
p_{Ut} M_{Dt} = \theta_{U, t} \times Y_t (Q_D)^{-\frac{1}{\epsilon}} Q_D [M_{Dt}, K_{Dt}] + (1 - \theta_{U, t}) \times cX_t M_{Ut}
$$

(15)

where Equation (15) is consistent with the outcome of the price formula contract in Blair and Kaserman (1987). Replacing Equation (15) in the expressions for firms’ operating profits above, we obtain $\Pi_{jt} \equiv Y_t \times \pi_{jt} [Z_t]$, where the function $\pi_{jt} [Z_t]$ is defined as

$$
\pi_{jt} [Z_t] \equiv \theta_{U, t} \times \Omega \times Z_t \times (K_{Ut})^\omega (K_{Dt})^{\omega},
$$

(16)

and the variable $Z_t \equiv (Y_t/X_t)^{\frac{\alpha D \alpha U}{(1-\alpha D)(1-\alpha U)}}$ is a monotone function of ratio of the downstream demand shock $Y_t$ and the upstream cost shock $X_t$. The parameters $\Omega > 0$ and $0 < \omega < 1$ in Equation (16) are defined as

$$
\omega \equiv \frac{(\alpha D - 1) (\varepsilon - 1)}{\alpha U \alpha D (\varepsilon - 1) - \varepsilon}, \quad \text{and}
$$

$$
\Omega \equiv \left( \frac{\alpha U \alpha D}{\varepsilon} (\varepsilon - 1) - 1 \right) \left( \frac{\alpha U \alpha D (\varepsilon - 1)}{\varepsilon \alpha} \right)^{\frac{\alpha U \alpha D (\varepsilon - 1)}{\alpha U \alpha D (\varepsilon - 1) - 1}}.
$$

In the extended model of Section 2, we derive firms’ operating profits in the segment in which they bargain following the same procedure. We then multiply the expression in Equation (16) by the factor $(1 - \gamma_j)$, and add an additional source of income equal to $\gamma_j K_j$ to obtain the expression in Equation (10).

Proof of Lemma 2

The derivation follows Carlson et al. (2004) and takes into account the more general definition of firms’ operating profits in Section 2. For any investment strategy $z_j$, we denote $A^-_{jt} = \frac{\pi_{jt} - \gamma_j K_j}{\delta} + \frac{\gamma_j K_j}{r} + \frac{\Delta \pi_{jt}}{\delta}$ the value of the assets in place of firm $j$ before investment, $A^+_{jt} = \frac{\pi_{jt} - \gamma_j K_j}{\delta} + \frac{\gamma_j K_j}{r} + \frac{\Delta \pi_{jt}}{\delta}$ the value of the assets in place of firm $j$ after investment. At the investment threshold $z_t = z_j$, the firm can pay $\kappa_j$ to increase the value of its assets in place from $A^-_{jt}$ to $A^+_{jt}$. Given exercise at $Z_t \geq z_j$, the value of the growth option to invest of firm $j$ is calculated as a perpetual
binary option with payoff \( V_{jt}^+ - V_{jt}^- - \kappa_j K_j \). The expected value of the growth option to invest is then given by 
\[
G_{jt} \equiv (A_{jt}^- - A_{jt}^+ - \kappa_j K_j) \left( \frac{Z_t}{z_j} \right)^\upsilon,
\]
where \( \left( \frac{Z_t}{z_j} \right)^\upsilon \) is the price of a contingent claim that pays 1 if the firm invests and 0 otherwise, and the parameter \( \upsilon > 1 \) is such that 
\[
\upsilon = \frac{1}{2} - \frac{r - \delta}{\sigma^2} + \left( \frac{r - \delta}{\sigma^2} - \frac{1}{2} \right)^2 + \frac{2r}{\sigma^2} \right)^{\frac{1}{2}},
\]
and the parameter \( \delta > 0 \) represents a convenience yield such that 
\[
\delta \equiv r + \eta\sigma_z - \frac{\sigma^2}{2} - \mu_z.\]
We focus on the case in which \( \delta > r \) to ensure a positive risk premium. For any investment strategy \( z_j \), we conclude that \( V_{jt} \) equals \( A_{jt}^- + G_{jt} \) if \( z_t < z_j \), and \( A_{jt}^+ \) if \( z_t \geq z_j \).

**Proof of Lemma 3**

We begin by considering the definition of excess returns \( R_{jt} \) given by 
\[
\mathbb{E}_t \left[ \frac{dV_{jt}}{V_{jt}} \right] \frac{1}{dt} + \pi_{jt} \frac{V_{jt}}{V_{jt}} - r = -\mathbb{E}_t \left[ \frac{dV_{jt}}{V_{jt}} d\xi_t \right] \frac{1}{dt} = \beta_{jt} \eta,
\]
where we follow Bustamante and Donangelo (2017) and define a firm’s beta or systematic risk loading such that 
\[
\beta_{jt} \equiv -\mathbb{E}_t \left[ \frac{dV_{jt}}{V_{jt}} d\xi_t \right] \frac{1}{dt}. \eta.
\]
Reordering terms in the equation above and using the definition of \( V_{jt} \) in this Appendix, we obtain the expression for a firm’s beta \( \beta_{jt} \) as shown in Equations (4) and (12). In the extended model with diversified sales, the constant \( \iota \) is defined as 
\[
\iota \equiv 1 + \upsilon \left( \frac{\delta}{r} - 1 \right) > 1.
\]

**Sorting Conditions in Sections 1-2**

The derivation of the sorting conditions of the model follows Bustamante (2015). For the sake of generality, we apply the definition of a firm’s value in the extended model. For any investment strategy \( z_j \), the preinvestment value of firm \( j \) is given by 
\[
V_j [Z_t] = \frac{\pi_{jt} - \gamma_j K}{\delta} + \gamma_j K + \left( \frac{Z_t}{z_j} \right)^\upsilon \left( \frac{\pi_j}{\delta} - \frac{\pi_j^-}{\delta} - \kappa_j K \right) + \frac{\Delta \pi_{jt}^+}{\delta} + \left( \frac{Z_t}{z_j} \right)^\upsilon \left( \frac{\Delta \pi_j^+}{\delta} \right) \bigg|_{Z_t = z_j}.
\]

Consider first the sorting condition the basic model in Section 1. We derive the preinvestment value of the firm with respect to both the investment cost \( \kappa_j \) and the threshold \( z_j \) to obtain the expression in Equation (5). This yields: 
\[
\frac{\partial}{\partial \kappa_j} \left( \frac{\partial V_{jt}}{\partial z_j} \right) \equiv \upsilon \frac{K}{z_j} \left( \frac{Z_t}{z_j} \right)^\upsilon > 0,
\]
such that firms with lower investment costs \( \kappa_j \) have an incentive to invest earlier.
As discussed in Section 1, the basic model would also predict that firms with lower initial installed capacity \( K_j \) are willing to invest earlier. To prove this statement, we derive the preinvestment value of the firm with respect to both the initial installed capacity \( K_j \) and the threshold \( z_j \). We assume that firms’ investment costs are the same so that \( \kappa_j = \kappa \). To simplify the notation, we further assume that \( \psi = \omega \) and \( \gamma_j = 0 \). The corresponding sorting condition yields:

\[
\frac{\partial}{\partial K_j} \left( \frac{\partial V_{jt}}{\partial z_j} \right) = \left( \frac{\kappa v}{z_j} - \left( \theta_{j,+} \Lambda \omega K_{-j,+}^\omega - \theta_{j,-} K_{-j,-}^\omega \right) K_j^\omega \right) (v-1) \frac{\omega \Omega}{\kappa_j} \left( \frac{Z_t}{z_j} \right) > 0. \tag{17}
\]

where Equation (17) is strictly positive as long as:

\[
\omega z_j < z_j^* \equiv \frac{\kappa K_j \delta v}{\omega (\theta_{j,+} \Lambda \omega K_{-j,+}^\omega - \theta_{j,-} K_{-j,-}^\omega )} K_j^\omega. \tag{18}
\]

The condition in Equation (18) holds for any parameter value since \( \omega < 1 \) and \( z_j^* \) is the (minimum) optimal threshold at which a firm may invest in equilibrium if relatively more patient firm \(-j\) were to accept the offer unconditionally.

Last, consider the sorting condition with respect to \( \gamma_j \) in the extended model of Section 2. We derive the preinvestment value of the firm with respect to both the parameter \( \gamma_j \) and the threshold \( z_j \) to obtain:

\[
\frac{\partial}{\partial \gamma_j} \left( \frac{\partial V_{jt}}{\partial z_j} \right) = -\Omega \left( \theta_{j,+} \Lambda \omega K_{-j,+}^\omega - \theta_{j,-} K_{-j,-}^\omega \right) K_j^\omega \frac{Z_t}{z_j} \right)^v > 0, \tag{19}
\]

where Equation (17) is strictly positive for any parameter value. Equation (19) predicts that, all else equal, firms with a less skin in the game in the segment in which the negotiation takes place (and hence higher \( \gamma_j \)) are relatively more patient than their peers to develop their growth opportunities.

Equation (17) implies that the qualitative predictions of the basic model on firms’ investment strategies in equilibrium hold either under Assumption 1 or under an alternative set of assumptions in which \( \kappa_j = \kappa \), \( \psi = \omega \), and \( K_U < K_D \). Similarly, Equation (19) implies that the qualitative predictions of the basic model on firms’ investment strategies also hold in the extension with multiple business segments when \( \kappa_j = \kappa \), \( K_j \equiv K \) and \( \gamma_U < \gamma_D \).

**Proof of Proposition 1**

We solve the sequential investment equilibrium by backward induction. Consider first the problem of firm \( D \) at \( t = \tau_D^* \). To avoid rejection by firm \( U \), firm \( D \) chooses the investment strategy that maximizes the value of firm \( U \), taking into account its own participation constraint. We solve for the optimal investment strategy of firm \( D \) by considering the Lagrangean:

\[
\mathcal{L}_D^* = V_U^+[z_D^*] - \lambda_D^* \left( V_D^+[z_D^*] - \frac{\pi_D^*[z_D^*]}{\delta} \right)
\]

where the second term is the product of the participation constraint of firm \( U \) at \( t = \tau_D^* \), and the corresponding multiplier \( \lambda_D^* \). The constraint ensures that firm \( D \) is indifferent between the disagreement outcome and the outcome
in which its growth opportunity is exercised. The first order conditions that stem from the optimization problem are:

\[ \frac{\partial L_s D}{\partial z} = 0, \quad \text{and} \quad \frac{\partial L_s D}{\partial \lambda} = 0, \]

where the first condition pins down the equilibrium threshold \( z_s D \), and the second condition pins down the equilibrium revenue share \( \theta_{U, \tau} \). The expressions for \( z_s D \) and \( \theta_{U, \tau} \) are reported in Proposition 1.

Consider now the problem of firm \( U \) at \( t = \tau_s U \). Firm \( U \) chooses the investment strategy that maximizes the value of firm \( D \) taking into account its own participation constraint. We thus solve for the optimal investment strategy of firm \( U \) by considering the Lagrangian:

\[ L_U^U = V_D^D[z_U] - \lambda_U^U \left( V_U^U[z_U] - \frac{\pi_U^U[z_U]}{\delta} \right) \]

where the second term is the product of the participation constraint of firm \( D \) at \( t = \tau_U^U \), and the corresponding multiplier \( \lambda_U^U \). The constraint ensures that firm \( D \) accepts the offer of firm \( U \) as long as its value after the investment of firm \( U \) is equal or larger than its value in case of disagreement with firm \( U \), i.e. the value of the assets in place of firm \( D \) before the investment of firm \( U \). The first order conditions that stem from the optimization problem are:

\[ \frac{\partial L_U^U}{\partial z_U} = 0, \quad \text{and} \quad \frac{\partial L_U^U}{\partial \lambda_U} = 0, \]

where the first condition pins down the equilibrium threshold \( z_U^U \), and the second condition pins down the revenue share \( \theta_{U, \tau_U^U} \). The expressions for \( z_U^U \) and \( \theta_{U, \tau_U^U} \) are shown in Proposition 1.

**Proof of Proposition 2**

Consider first the derivation of the Pareto optimal clustering investment strategies. Firm \( U \) chooses the investment strategy that maximizes the value of firm \( U \) taking into account its own participation constraint. We solve for the optimal investment strategy of firm \( U \) under joint investment by considering the Lagrangian:

\[ L^{c*} = V_D^D[z^{c*}] - \lambda^c \left( V_U^U[z^{c*}] - \frac{\pi_U^U[z^{c*}]}{\delta} \right) \]

where the second term is the product of the participation constraint of firm \( U \) at \( t = \tau^{c*} \), and the corresponding multiplier \( \lambda^{c*} \). The optimization problem ensures that firm \( D \) accepts the offer of firm \( U \). The first order conditions that stem from the optimization problem are:

\[ \frac{\partial L^{c*}}{\partial z^{c*}} = 0, \quad \text{and} \quad \frac{\partial L^{c*}}{\partial \lambda^{c*}} = 0, \]

where the first condition pins down the Pareto optimal clustering threshold \( z^{c*} \), and the second condition pins down the corresponding revenue share \( \theta_{U, \tau^{c*}} \). The expressions for \( z^{c*} \) and \( \theta_{U, \tau^{c*}} \) are shown in Proposition 2.

Consider now the alternative clustering equilibrium thresholds \( z^c \) so that \( z^{c*} < z^c < z_s D \). While firm \( D \) optimizes
joint future expected value at \( z^* \), a clustering equilibrium in which firm \( D \) extracts all future supply chain value is sustainable as long as \( z^c < z^c_D \). Hence if firm \( U \) makes a revenue sharing offer to firm \( D \) in the interval \( z^c < z^c < z^s_D \), firm \( D \) accepts, and both firms invest jointly in equilibrium. The corresponding revenue share of firm \( U \) is so that its participation constraint is binding, namely:

\[
\theta_c[z^c] \equiv \frac{1}{2} \left( \frac{1}{\Lambda} \right)^{\omega + \psi} + \frac{\kappa_U (\Lambda - 1) \kappa \delta}{\Omega (\Lambda K)^{\omega + \psi} z^c}.
\] (20)

Replacing \( z^c \) by the Pareto optimal threshold \( z^c \) in Equation (20), we obtain the expression for the revenue share in the Pareto optimal equilibrium as shown in Proposition 2.

**Proof of Proposition 3**

Consider the value of firm \( U \) under the sequential investment and joint investment equilibrium strategies. In the sequential investment equilibrium, the value of firm \( D \) at \( Z_t < z^s_U \) is equal to

\[
V^s_D[\text{z}_t] = \frac{\Omega Z_t}{2 \delta} K^{\omega + \psi} + \frac{\kappa_D K}{v - 1} \left( \frac{Z_t}{z^s_D} \right)^v + \frac{\kappa_U K}{v - 1} \left( \frac{Z_t}{z^s_U} \right)^v.
\]

In the Pareto optimal clustering equilibrium, the value of firm \( U \) at \( Z_t < z^c \) is equal to

\[
V^c_U[\text{z}_t] = \frac{\Omega Z_t}{2 \delta} K^{\omega + \psi} + \left( \frac{\kappa_D + \kappa_U}{v} \right) \left( Z_t \right)^v.
\]

Subtracting both expressions and reordering terms, we obtain

\[
V^s_U[\text{z}_t] - V^c_U[\text{z}_t] = \frac{K}{v - 1} \left( \kappa_U + \kappa_D \left( \frac{\kappa_U (\Lambda^\omega - 1)}{\kappa_D (\Lambda^\omega - 1)} \right)^v \left( \frac{\kappa_U (\Lambda^\omega - 1)}{\kappa_D + \kappa_U} \right) \left( \frac{\Lambda^\omega - 1}{\Lambda^\omega - 1} \right)^v \right) > 0,
\]

so that supply chain growth options are more valuable when exercised sequentially. Consistent with Weeds (2002) and Pawlina and Kort (2006), when firms invest so that joint surplus is maximized, joint investment embeds inefficient investment delay for one of the two projects.

**Proof of Corollary 2**

Consider the basic model in Section 1 in which \( \gamma_j = 0 \). For any investment strategy, the definition of firms’ betas in Lemma (3) implies that the covariance in betas depends on the covariance in earnings-to-value ratios, namely

\[
sign[cov(\beta_{Ut}, \beta_{Dt})] = sign[cov(V_{Ut} - \frac{\pi_{Ut}}{z^s_U}, V_{Dt} - \frac{\pi_{Dt}}{z^s_D})].
\]

In the sequential investment equilibrium, each firm expects an increase in its profits upon the investment of its supply chain peer, where \( \Delta \pi_{Dt}^L > 0 \) and \( \Delta \pi_{Ut}^L > 0 \). Consider first the interval \( \text{z}_U < Z_t < z^s_D \). In this case, firm \( U \) expects an increase in its profits, so that its earnings-to-price ratio is higher than unity before \( \tau^h_D \) and equal to unity.
thereafter. The equilibrium strategies in Proposition 1 imply that an amount worth $G_{Dt}$ gets fully transferred from firm $D$ to firm $U$ in equilibrium at the stopping time $\tau^D_s$, so that $\Delta \pi^+_s \equiv G_{Dt}$. As a result, $V_{Ut} - \frac{\pi^+_s}{\delta} = \frac{\Delta \pi^+_s}{\delta} > 0$.

In contrast, in the the interval $z^U_t < Z_t < z^D_t$, firm $D$ expects the value of its assets in place to remain constant upon investment, and its earnings-to-price ratio equals unity before and after investment. It holds that $V_{Dt} - \frac{\pi^-}{\delta} = 0$: firm $D$ is equal to the value of its assets in place before and after investment, so that $\pi^- = \frac{\pi^-}{\delta}$. Put together, these results imply that

$$\text{cov} \left( \frac{\Delta \pi^+_s}{\delta}, \frac{\pi^+_s}{\delta} - \frac{\pi^-}{\delta} \right) = 0,$$

so that $\text{cov} (\beta_{Ut}, \beta_{Dt}) = 0$ if $z^U_t < Z_t < z^D_t$.

Consider now the interval $Z_t < z^U_t$. In this case, firm $U$ expects a reduction in its profits at $\tau^U_s$, and its earnings-to-price ratio to increase above unity until firm $D$ invests later in time. As a result, $V_{Ut} - \frac{\pi^+_s}{\delta} = -G_{Ut} - G_{Dt} + \frac{\Delta \pi^+_s}{\delta}$. Namely, firm $D$ fully transfers $GU_t$ to firm $D$ upon investment, and it further pays upfront for $G_{Dt}$, which it fully recovers later on at $\tau^U_s$. In contrast, firm $D$ expects an increase in its profits at $\tau^U_s$, so that its earnings-to-price ratio decreases upon the investment of firm $U$ and then remains constant and equal to unity. More formally, $V_{Dt} - \frac{\pi^-}{\delta} = \frac{\Delta \pi^+_s}{\delta}$. The equilibrium strategies in Proposition 1 further imply that $\Delta \pi^+_s = G_{Ut}$. Put together, this implies that

$$\text{cov} \left( V_{Ut} - \frac{\pi^+_s}{\delta}, V_{Dt} - \frac{\pi^-}{\delta} \right) = \text{cov} (-G_{Ut}, G_{Ut}) < 0,$$

so that $\text{cov} (\beta_{Ut}, \beta_{Dt}) < 0$ if $Z_t < z^U_t$. We conclude that betas comove negatively before $\tau^U_t$ since firm $D$ extracts the growth option value of firm $U$ or $G_{Ut}$ and makes firm $D$ pay in advance for $G_{Dt}$. In contrast, the comovement in betas is zero at $\tau^D_s$, since firm $D$ is already worth the preinvestment value of its assets in place, while firm $U$ gains $G_{Dt}$ and hence is finally worth the value of its assets in place before any investment takes place.

**Database Construction**

Stock returns come from the CRSP monthly files. We keep observations related to common equity (share code 10 or 11) and drop observations with missing returns. Market equity is the product of the absolute value of price (PRC) and shares outstanding (SHROUT) divided by 1000. Firm accounting data comes from the Compustat Fundamentals Annual file. Shareholder and book equity are calculated as in Daniel and Titman (2006). We proxy preferred equity using total preferred stock (PSTKQ) and impute a zero value if missing. Total debt is the sum of long-term debt and debt in current liabilites (DLCQ). Capital expenditures are the item CAPX. Book-to-market equity is the ratio of contemporaneous book and market equity. Investment-to-capital is the ratio of quarterly capital expenditure and contemporaneous property, plant, and equipment (PPENTQ). Book leverage is the ratio of book debt to book assets. If any of the inputs to financial ratios is missing we treat the observation as missing. All accounting variables are winsorized at the 1st and 99th percentiles of their cross-sectional distributions each quarter.

To classify firms into customers and suppliers at the industry level, we focus on two Input-Output (hereafter, IO) tables produced by the BEA, USE and MAKE. The USE table represents the dollar value of commodities purchased
by each industry. The MAKE table shows the dollar value of the commodities produced by each industry. We perform minor adjustments to the USE and MAKE tables to accommodate differences between the IO and NAICS industry classifications. Specifically, we consolidate the 12 sub-industries related to construction (IO codes 23xxxx) into a single industry because the BEA does not provide a granular mapping from these sub-industries to NAICS. We handle the 2 sub-industries related to real estate (IO codes 531xxx) in the same manner. Our final USE and MAKE tables contain 377 industries. We use the table provided by the BEA to map each Compustat firm-year into the corresponding IO code using historical NAICS. The mapping links the 15-, 71-, and 389-industry IO tables into 2007 NAICS industry ranges. At the 389-industry level, each NAICS code maps to a single IO industry except for construction-related and real-estate-related industries which map to more than one IO industry. We consolidate the 12 sub-industries related to construction (IO codes 23xxxx) into a single industry. We handle the 2 sub-industries related to real estate (IO codes 531xxx) in the same manner.
Figure 1: Leader-follower equilibrium strategies as a function of $\kappa_D$. This figure illustrates the predictions of the basic model regarding firms' investment strategies $z^*_j$, revenue shares $\theta_{j,-\tau}$, values $V_{jt}$ and betas $\beta_{jt}$ in the sequential investment equilibrium for $j = U, F$ and $\kappa_U < \kappa_D$. Solid lines correspond to firm $U$ and dashed lines to firm $D$. Red corresponds to firms' strategies when firm $U$ invests at $z^*_U$; magenta corresponds to firms' strategies when firm $D$ invests at $z^*_D$. The parameter choice is so that $\kappa_U = 1$, $\Lambda = 2.5$, $\alpha_U = \alpha_D = 0.7$, $\varepsilon = 3$, $K = 1$, $\sigma_Y = 0.6$, $\sigma_X = 0.01$, $\mu_Y = 0.02$, $\mu_X = 0.015$, $r = 0.05$, $\eta = 0.05$ and $c = 0.001$. 
Figure 2: Clustering equilibrium strategies as a function of $\kappa_D$. This figure illustrates the predictions of the basic model regarding firms' investment strategies $z^*_j$, revenue shares $\theta_{j*\tau}$, values $V_{jt\tau}$ and betas $\beta_{jt\tau}$ in the simultaneous investment equilibrium for $j = U, F$ and $\kappa_U < \kappa_D$. Solid blue lines correspond to firm $U$ and dashed blue lines to firm $D$. The dashed dotted blue line represents the clustering strategy in which firm $D$ attains the lowest value under joint investment. The parameter choice is so that $\kappa_U = 1$, $\Lambda = 2.5$, $\alpha_U = \alpha_D = 0.7$, $\varepsilon = 3$, $K = 1$, $\sigma_Y = 0.6$, $\sigma_X = 0.01$, $\mu_Y = 0.02$, $\mu_X = 0.015$, $r = 0.05$, $\eta = 0.05$ and $c = 0.001$. 
Figure 3: Comparative Statics in the Leader-Follower equilibrium. This figure illustrates comparative statics of the model with respect to $\epsilon$, $\sigma_Y$ and $\alpha_D$, for both the investment thresholds $z_j$ and the revenue shares $\theta_{j,\tau}$ in the leader-follower equilibrium. The parameter choice is so that $\kappa_U = 1$, $\Lambda = 2.5$, $\alpha_U = \alpha_D = 0.7$, $\varepsilon = 3$, $K = 1$, $\sigma_Y = 0.6$, $\sigma_X = 0.01$, $\mu_Y = 0.02$, $\mu_X = 0.015$, $r = 0.05$, $\eta = 0.05$ and $c = 0.001$. 

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Figure 4: Equilibrium Dynamics of Firms’ Risk Loadings in the Basic Model. This figure illustrates the equilibrium dynamics of firms’ risk loadings $\beta_{jt} j = U, F$ and $\kappa_U < \kappa_D$ in the leader-follower equilibrium. The top panel illustrates the dynamics of the risk loading of the upstream firm $U$. The bottom panel illustrates the dynamics of the risk loading of the downstream firm $D$. The parameter choice is so that $\kappa_U = 2$, $\kappa_D = 6$, $\Lambda = 5$, $\alpha_U = \alpha_D = 0.5$, $\varepsilon = 3$, $K = 1$, $\sigma_Y = 0.6$, $\sigma_X = 0.01$, $\mu_Y = 0.02$, $\mu_X = 0.015$, $r = 0.02$, $\eta = 0.03$ and $c = 0.001$. We use 800 simulations of the Brownian shocks.
Figure 5: Comparative Statics of Supply Chain Risk Loadings of Growth Opportunities. This figure illustrates the comparative statics of $\sigma_Z \nu$, which corresponds to the risk loading of the growth opportunities of all firms in a given supply chain. The comparative statics of $\nu$ in isolation are shown for completeness. The parameter choice is so that $\kappa_U = 1$, $\Lambda = 2.5$, $\alpha_U = \alpha_D = 0.7$, $\varepsilon = 3$, $K = 1$, $\sigma_Y = 0.6$, $\sigma_X = 0.01$, $\mu_Y = 0.02$, $\mu_X = 0.015$, $r = 0.05$, $\eta = 0.05$ and $c = 0.001$. 
Figure 6: Equilibrium strategies as a function of $\gamma_D$. This figure illustrates the predictions of the extended model regarding firms’ investment strategies $z_j$, revenue shares $\theta_j$, values $V_j$, and betas $\beta_j$, in the sequential and joint investment equilibria for $j = U, F$, $\kappa_j \equiv \kappa$, and $\gamma_U < \gamma_D$. Solid lines correspond to firm $U$ and dashed lines to firm $D$. Red corresponds to firms’ strategies when firm $U$ invests at $z^*_U$; magenta corresponds to firms’ strategies when firm $D$ invests at $z^*_D$. Blue lines correspond to the joint investment equilibrium, and the dashed dotted blue line represents the clustering strategy in which firm $D$ attains the lowest value under joint investment. The parameter choice is so that $\kappa_U = \kappa_D = 1$, $\Lambda = 2.5$, $\alpha_U = 0.75$, $\alpha_D = 0.8$, $\varepsilon = 3$, $K = 1$, $\sigma_Y = 0.6$, $\sigma_X = 0.01$, $\mu_Y = 0.02$, $\mu_X = 0.015$, $r = 0.05$, $\eta = 0.05$, $c = 0.001$, and $\gamma_U = 0.02$. 
Figure 7: Equilibrium Dynamics of Risk Loadings in the Extended Model with $\kappa_U < \kappa_D$ and $\gamma_j \equiv \gamma$. This figure illustrates the equilibrium dynamics of firms’ risk loadings $\beta_{jt}$, $j = U, F$ and $\kappa_U < \kappa_D$ in the leader-follower equilibrium of the extended model. The top panel illustrates the dynamics of the risk loading of the upstream firm $U$. The bottom panel illustrates the dynamics of the risk loading of the downstream firm $D$. The parameter choice is so that $\kappa_U = 2$, $\kappa_D = 6$, $\Lambda = 5$, $\alpha_U = \alpha_D = 0.5$, $\varepsilon = 3$, $K=1$, $\sigma_Y = 0.6$, $\sigma_X = 0.01$, $\mu_Y = 0.02$, $\mu_X = 0.015$, $r = 0.02$, $\eta = 0.03$ and $c = 0.001$. We use 800 simulations of the Brownian shocks.
The table below presents summary statistics of the variables used in the working dataset. The sample period is from 1997 to 2017. The dataset consists of supply-chain pairs of an industry $U$ (upstream) and an industry $D$ downstream, as classified by BEA’s 389 industries input/output tables of 2007. $Ret$ represents realized returns obtained from CRSP’s monthly dataset and then annualized. $DifRetD$ is the difference between $RetD$ and $RetU$ for a given supply chain pair. $Btm$ represents the book-to-market ratio, $Inv$ the investment-to-capital ratio, and $Lev$ the book leverage ratio of industry $j$. All accounting variables are constructed using the Compustat Annual data. The variables $ImpU$ and $ImpD$ are constructed as in Ahern (2012), using the information from BEA’s 389 industries input/output tables of 2007. $ImpU$ is the ratio of the value of inputs of firm $U$ over total output of firm $D$. $ImpD$ is the ratio of purchases of firm $D$ over total sales of firm $U$.

<table>
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<tr>
<th>Variable</th>
<th>Obs</th>
<th>Mean</th>
<th>Std. Dev.</th>
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<th>p50</th>
<th>p75</th>
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Table 2
Realized Returns and Vertical Bargaining Power

This table presents estimates and normalized beta coefficients in parentheses of Fama-MacBeth regressions based on five alternative specifications. Specifications I and II are of the form

\[
\text{DifRet}_{it} = c_{0,t} + c_{1,t} \text{Measure}_{Uit} + c_{2,t} \text{Measure}_{Dit} + \epsilon_{it}
\]

where \(\text{DifRet}_{it}\) is the difference between the annualized stock returns of industries \(D\) and \(U\) for a given supply chain pair \(i\) in year \(t\), and \(\text{Measure}_j\) denotes the variables capturing relative bargaining power of industry \(j\) in the supply chain pair \(i\), described in Table 1. \(\text{Measure}\) equals \(\text{Imp}\) in Specification I, while it equals \(\text{Btm}\) in Specification II. The remaining specifications add controls to assess the robustness of the results in Specifications I and II. \(\text{Lev}\) denotes book value of leverage. The sample period is 1997 to 2017. *, **, and *** indicate significance levels of 5%, 1%, and 0.1%, respectively.

<table>
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<th>Regression Specification</th>
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<th>(II)</th>
<th>(III)</th>
<th>(IV)</th>
<th>(V)</th>
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<td>(\text{Imp}_U)</td>
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<td>-0.014***</td>
<td>-0.023**</td>
<td>-0.024***</td>
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<tr>
<td></td>
<td></td>
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<td>(-0.029)</td>
<td>(-0.031)</td>
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<td></td>
<td>(\text{Imp}_D)</td>
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<td></td>
<td></td>
<td>(0.010)</td>
<td>(0.013)</td>
<td>(0.001)</td>
<td>(0.001)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(\text{Btm}_U)</td>
<td>0.177***</td>
<td>0.178***</td>
<td>0.176***</td>
<td>0.148***</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.181)</td>
<td>(0.182)</td>
<td>(0.180)</td>
<td>(0.153)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(\text{Btm}_D)</td>
<td>-0.190***</td>
<td>-0.189***</td>
<td>-0.191***</td>
<td>-0.157***</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(-0.206)</td>
<td>(-0.206)</td>
<td>(-0.208)</td>
<td>(-0.168)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(\text{Btm}_U \times \text{Imp}_U)</td>
<td>0.014</td>
<td>0.012</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.014)</td>
<td>(0.012)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(\text{Btm}_D \times \text{Imp}_D)</td>
<td>0.011*</td>
<td>0.012**</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.016)</td>
<td>(0.018)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(\text{Lev}_U)</td>
<td></td>
<td></td>
<td></td>
<td>-0.184***</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(-0.058)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(\text{Lev}_D)</td>
<td></td>
<td></td>
<td></td>
<td>0.164***</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(0.051)</td>
<td></td>
</tr>
<tr>
<td>Observations</td>
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<td>1,015,247</td>
<td>1,015,247</td>
<td>1,015,247</td>
<td>1,015,247</td>
<td></td>
</tr>
<tr>
<td>R-squared</td>
<td>0.001</td>
<td>0.071</td>
<td>0.072</td>
<td>0.072</td>
<td>0.084</td>
<td></td>
</tr>
</tbody>
</table>
Table 3
Supply Chain Comovement in Realized Returns

This table presents estimates and normalized beta coefficients in parentheses of panel regressions of the form

$$\text{RetD}_{it} = c_0 + c_1 \text{RetU}_{it} + c_2 + c_3,i + \epsilon_{it},$$

where Ret denotes monthly realized returns. Panels A and B report the results of running the regression above in subsamples defined by the terciles of two alternative sorting variables. Panel A uses VarImp as the sorting variable, where VarImp captures the cross sectional variation in bargaining power within a given supply chain pair. Panel B uses VarBtm as the sorting variable, where VarImp captures the cross sectional variation in book-to-market ratios within a given supply chain pair. The sample period is 1997 to 2017. *, **, and *** indicate significance levels of 5%, 1%, and 0.1%, respectively.

### Panel A: Sorts by VarImp

<table>
<thead>
<tr>
<th>Dep. Variable</th>
<th>Low</th>
<th>Medium</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td>RetU</td>
<td>0.347***</td>
<td>0.292***</td>
<td>0.253***</td>
</tr>
<tr>
<td></td>
<td>(0.302)</td>
<td>(0.282)</td>
<td>(0.268)</td>
</tr>
<tr>
<td>Observations</td>
<td>4,122,923</td>
<td>4,122,689</td>
<td>4,122,706</td>
</tr>
<tr>
<td>Adjusted R-squared</td>
<td>0.126</td>
<td>0.120</td>
<td>0.115</td>
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</table>

### Panel B: Sorts by VarBtm

<table>
<thead>
<tr>
<th>Dep. Variable</th>
<th>Low</th>
<th>Medium</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td>RetU</td>
<td>0.324***</td>
<td>0.314***</td>
<td>0.268***</td>
</tr>
<tr>
<td></td>
<td>(0.314)</td>
<td>(0.302)</td>
<td>(0.258)</td>
</tr>
<tr>
<td>Observations</td>
<td>4,024,800</td>
<td>4,024,788</td>
<td>4,024,786</td>
</tr>
<tr>
<td>Adjusted R-squared</td>
<td>0.122</td>
<td>0.116</td>
<td>0.104</td>
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</tbody>
</table>
### Table 4

**Investment and Vertical Bargaining Power**

This table presents estimates and normalized beta coefficients in parentheses of Fama-MacBeth regressions based on five alternative specifications. Specifications I and II are of the form

\[ \text{DifInvD}_{it} = c_{0,t} + c_{1,t} \text{Measure}_{U, it} + c_{2,t} \text{Measure}_{D, it} + \epsilon_{it}, \]

where \( \text{DifInvD} \) is the difference between the investment-to-capital ratios of industries \( D \) and \( U \) for a given supply-chain pair \( i \) in year \( t \), and \( \text{Measure}_j \) denotes the variables capturing relative bargaining power of industry \( j \) in the supply chain \( i \), described in Table 1. \( \text{Measure} \) equals \( \text{Imp} \) in Specification I, while it equals \( \text{Btm} \) in Specification II. The remaining specifications add controls to assess the robustness of the results in Specifications I and II. \( \text{Lev} \) denotes book value of leverage. The sample period is 1997 to 2017. *, **, and *** indicate significance levels of 5%, 1%, and 0.1%, respectively.

<table>
<thead>
<tr>
<th>Regression Specification</th>
<th>Dep. Variable</th>
<th>(I)</th>
<th>(II)</th>
<th>(III)</th>
<th>(IV)</th>
<th>(V)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ImpU</td>
<td>-0.000</td>
<td>-0.003***</td>
<td>-0.013***</td>
<td>-0.016***</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(-0.001)</td>
<td>(-0.010)</td>
<td>(-0.049)</td>
<td>(-0.061)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>ImpD</td>
<td>0.007***</td>
<td>0.008***</td>
<td>0.007***</td>
<td>0.007***</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.043)</td>
<td>(0.048)</td>
<td>(0.043)</td>
<td>(0.042)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>BtmU</td>
<td>0.085***</td>
<td>0.085***</td>
<td>0.084***</td>
<td>0.064***</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.259)</td>
<td>(0.259)</td>
<td>(0.254)</td>
<td>(0.196)</td>
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</tr>
<tr>
<td></td>
<td>BtmD</td>
<td>-0.064***</td>
<td>-0.065***</td>
<td>-0.065***</td>
<td>-0.054***</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(-0.207)</td>
<td>(-0.208)</td>
<td>(-0.209)</td>
<td>(-0.173)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>BtmU x ImpU</td>
<td>0.014***</td>
<td>0.016***</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.040)</td>
<td>(0.047)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>BtmD x ImpD</td>
<td>0.001</td>
<td>0.002</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.003)</td>
<td>(0.010)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>LevU</td>
<td></td>
<td></td>
<td>-0.104***</td>
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<td></td>
<td></td>
<td></td>
<td>(-0.097)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>LevD</td>
<td></td>
<td></td>
<td>0.118***</td>
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<td></td>
<td></td>
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<td>(0.111)</td>
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</tr>
<tr>
<td>Observations</td>
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<td>1,013,331</td>
<td>1,013,331</td>
<td>1,013,331</td>
<td>1,013,331</td>
<td></td>
</tr>
<tr>
<td>R-squared</td>
<td>0.002</td>
<td>0.067</td>
<td>0.069</td>
<td>0.070</td>
<td>0.187</td>
<td></td>
</tr>
</tbody>
</table>