Risk Management with Inventory Buybacks*

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Abstract

We study buyback clauses as an operational hedge against demand risk. Using Korean value-added tax invoices from 2017Q1–2021Q4, we identify buyback relationships as supplier–customer dyads with pre-COVID reciprocal flows. Although only 4.2% of active dyads exhibit such flows, they mediate 46.9% of B2B sales and link nearly half of firms. In an entropy-balanced difference-in-differences design around COVID-19 with dyad and firm-by-year fixed effects, customer-to-supplier sales rise by 10.4% and supplier-to-customer sales fall by 3.7%, consistent with customers exercising the return option. Suppliers redeploy returned goods to other buyers. Buybacks form via capacity–need matching and are honored by high-capacity suppliers.

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1 Introduction

Large demand collapses expose a fundamental gap in firms' risk management. While corporate finance theory emphasizes that reducing cash-flow volatility can raise firm value (Smith and Stulz, 1985; Froot et al., 1993), most formal risk management tools are designed for contractible, near-term exposures (e.g., exchange rates, interest rates, or commodity prices), and provide limited protection against broad, non-contractible demand shocks (Rampini et al., 2014). Recent work therefore calls for a broader view of resilience that goes beyond financial hedging toward mechanisms embedded in firms' real operations and relationships (Stulz, 2024). One natural yet underexplored candidate is *contractual hedging* inside supply chains: when markets are incomplete, firms may reallocate risk through bilateral agreements that function like insurance but are sustained by ongoing trade rather than by formal legal enforcement.

When consumer demand collapses, firms often face a risk that financial markets cannot easily hedge: excess inventory. While corporate finance theory emphasizes that reducing cash-flow volatility increases firm value (Smith and Stulz, 1985; Froot et al., 1993), standard financial tools are designed for standardized risks such as exchange rates, interest rates, and commodity prices. They provide little protection against the idiosyncratic risk that a firm's products simply do not sell (Rampini et al., 2014). Because firms cannot buy a financial derivative to hedge against specific demand failures, they must look for resilience within their real operations (Stulz, 2024). A natural but underexplored solution is contractual hedging inside the supply chain: explicit or implicit agreements that allow buyers to return unsold goods to suppliers, effectively functioning as insurance sustained by ongoing trade rather than by formal legal enforcement.

This paper studies a prominent form of such contractual hedging—informal inter-firm inventory buyback arrangements.[1] In a buyback agreement, an upstream supplier commits to repurchase unsold goods from a downstream customer at a pre-specified refund price. Economically, the clause grants the customer a put option on excess inventory: the customer can liquidate leftover stock back to the supplier, limiting downside exposure when demand is weak. Classic operations work shows that such clauses can mitigate under-ordering and

[1] We use the term "buyback" to refer to a contractual inventory return clause (often called an *inventory buyback* or *return* agreement), not to be confused with corporate share repurchases.

improve efficiency (Pasternack, 1985), and they are widely discussed in specific industries (e.g., publishing, fashion, and electronics distribution). Yet we lack economy-wide evidence on three basic questions that matter for economics and finance: How prevalent are these private risk-sharing contracts in the aggregate production network? Do they materially buffer firms when demand collapses? And if the promise is difficult to enforce legally—because return eligibility, condition, and timing are difficult to specify and verify—when do such arrangements remain effective under stress?

We answer these questions using confidential value-added tax (VAT) invoice records from South Korea spanning 2017Q1–2021Q4, and we exploit the onset of COVID-19 as a large, sudden negative demand shock. Korea's VAT system provides a sharp revealed-preference signature of buybacks: unsold-inventory buybacks are recorded as a *new positive taxable sale in the reverse direction* (customer→supplier), whereas defect- or warranty-related adjustments are recorded as corrections to the original transaction (negative entries). This institutional distinction allows us to identify buyback relationships at scale using transaction flows alone. Concretely, we classify a supplier–customer dyad as a buyback relationship if it exhibits strictly positive two-way invoicing in the pre-COVID period, consistent with the presence of a buyback option that is exercised intermittently in normal times and becomes valuable precisely in downturns.

The first finding is that buybacks are rare by count but central by value. Only about 4.2% of active supplier–customer dyads exhibit pre-COVID reciprocal flows, yet these links mediate roughly 46.9% of total business-to-business (B2B) sales and involve nearly half of firms. In other words, buybacks are concentrated in the economically most important relationships—exactly where demand risk, inventory exposure, and relationship-specific contracting are likely to be first-order. This fact alone suggests that a large share of production-network activity takes place on links endowed with state-contingent clauses, motivating a contractual perspective on how shocks propagate through supply chains.

To interpret the evidence and discipline the empirical design, we develop a simple framework in which buybacks are an incomplete, relational contract. A buyback clause reallocates inventory risk from the downstream firm to the upstream supplier, encouraging higher baseline orders and larger forward trade in normal times. But because the refund promise is difficult to enforce in court, it is sustained by the value of future trade: suppliers honor returns when the short-run gain from reneging is outweighed by the discounted loss of rela-

tionship rents. The framework yields four testable implications that guide the analysis: (i) higher baseline forward trade on buyback links; (ii) state-contingent activation in downturns, with a spike in customer-to-supplier flows (returns) and a relative decline in forward sales; (iii) concentration of buybacks in strong, durable relationships with high continuation value; and (iv) capacity–need matching, in which riskier buyers sort into buybacks with suppliers better able to absorb and redeploy returned inventory.

Empirically, we implement a difference-in-differences (DiD) design around COVID-19 that compares buyback dyads to observationally similar non-buyback dyads, fixing buyback status using only pre-2020 data to ensure treatment is defined purely ex ante. We estimate dyad-level panels with dyad fixed effects and supplier×year and customer×year fixed effects, and we use entropy balancing to align treated and control dyads on rich pre-COVID covariates and pre-trends. The results show that buybacks operate as contingent insurance when demand collapses. During 2020–2021, reciprocal sales (customer→supplier) rise by about 10.4% in buyback dyads relative to matched controls, while forward sales (supplier→customer) fall by an additional 3.7%. This reversal in net flow direction is precisely what a buyback option predicts: downstream firms shed excess inventory by exercising the return clause, substituting away from new purchases when demand is weak. Consistent with the demand-risk mechanism, the insurance effect is strongest where exposure to final demand is greatest: return spikes are significantly larger for consumer-facing buyers and are most pronounced in retail and wholesale supply chains.

Crucially, the shock does not simply move losses upstream and stop there. We trace the destination of returned inventory and find systematic redeployment by suppliers. After repurchasing goods, suppliers expand shipments through their other customer links—first along existing relationships (an intensive-margin adjustment) and later by forming new outlets (an extensive-margin adjustment). Thus, buybacks convert an idiosyncratic demand shortfall at one downstream buyer into reallocation across the supplier's broader network, sustaining trade and mitigating waste. This highlights a decentralized micro-insurance margin inside production networks: risk is pooled through relationship-based contracting and realized through inventory re-routing, potentially dampening downstream cascades that would otherwise translate demand shortfalls into output losses.

Finally, we examine when buybacks arise and when they are honored. Consistent with relational contracting, buybacks form disproportionately in geographically proximate, durable,

and continuous trading relationships—settings where monitoring is easier and continuation value is high. Formation also reflects capacity–need matching: buyers with more pre-COVID volatile sales growth (greater demand risk) are more likely to be buyback customers, while their suppliers exhibit lower pre-COVID volatility and broader redeployment capacity. Yet the COVID shock reveals that not all buybacks provide equal insurance. Conditional on adoption, buyback promises are honored primarily by high-capacity suppliers—those with steadier pre-pandemic sales, larger scale, higher profitability, and greater operational efficiency—whereas weaker suppliers are more likely to fail to absorb returns. In short, informal insurance is only as credible as the supplier's ability and incentives to pay in bad states.

Our findings contribute to four strands of work. First, we broaden the corporate risk-management toolkit by documenting a large-scale operational hedge embedded in product-market relationships: inventory buybacks that shift demand and inventory risk upstream. This complements the evidence on derivatives-based hedging and its value implications (Nance et al., 1993; Bartram et al., 2011) and speaks to why firms may rely on nonfinancial hedges when financial hedging is incomplete (Rampini et al., 2014). It also complements recent evidence on contractual hedges such as noncancelable supply contracts (Almeida et al., 2017, 2020). Second, we extend the inter-firm finance literature by showing that suppliers provide state-contingent insurance—not only liquidity through trade credit—to downstream firms (Petersen and Rajan, 1997; Burkart and Ellingsen, 2004; Giannetti et al., 2011). Third, we provide economy-wide evidence that such risk sharing is sustained by relational contracting and is honored in bad states when continuation value and supplier capacity make the promise credible (Baker et al., 2002; Levin, 2003; MacLeod, 2007). Fourth, we add a contractual dimension to production-network economics: buyer–supplier links are not homogeneous conduits of shocks. Links endowed with state-contingent clauses transmit and absorb demand shocks differently, and during COVID-19 buybacks helped transform a demand collapse into inventory reallocation rather than output loss, speaking to mechanisms that may dampen amplification in supply chains (Acemoglu et al., 2012; Carvalho, 2014; Baqaee and Farhi, 2019; di Giovanni et al., 2014; Boehm et al., 2019; Guerrieri et al., 2022a; Chetty et al., 2024).

2 Conceptual Framework

This section sketches a simple framework for why inventory buybacks provide insurance to downstream firms and, when informal, concentrate in durable, high-value relationships. The formal model, comparative statics, and extensions are in Internet Appendix Section OA, which frames buybacks as an *incomplete* contract: key return contingencies are difficult to verify at low cost, so performance is sustained by the value of future trade rather than by legal enforcement (Williamson, 1975, 1985).

An upstream supplier and a downstream customer trade repeatedly. Each period, the customer orders inventory before demand is realized, so realized sales may fall short and leave unsold stock. Under standard spot trade, the customer pays a wholesale price and bears the inventory risk. A buyback arrangement adds a state-contingent clause: the customer pays a higher wholesale price up front and, in exchange, receives a refund for each unsold unit returned at the end of the period. Economically, the clause gives the buyer a buyback option on excess inventory. The key friction is enforcement. Whether inventory is eligible for return depends on product condition, timing, and whether units are genuinely unsold—features that are difficult to specify and verify in a way that is inexpensive to enforce. We therefore treat the refund promise as informal and sustained by the value of the ongoing relationship rather than by courts.

To connect buybacks to risk management, we assume the downstream firm is effectively risk averse (e.g., a CEO whose incentives load on profit volatility) and therefore behaves conservatively in inventory decisions. A buyback limits the downside in weak-demand states by guaranteeing a liquidation value for leftover stock, reducing the buyer's exposure to demand risk. To isolate insurance from expected transfers, we consider a benchmark in which the higher wholesale price under buybacks reflects the supplier's *expected* refund liability. Under this benchmark, buybacks primarily reallocate risk rather than expected surplus: they make the buyer's payoff less sensitive to demand fluctuations. As a result, the buyer is willing to order more in normal times. Because buybacks also raise the unit invoice price, forward invoice values should be higher in buyback relationships even absent changes in final demand.

The refund is most valuable precisely when demand is low and returns are large, which creates a temptation for the supplier to renege in bad states. We capture this intuition with

a simple grim trigger logic: if the supplier ever fails to honor refunds, the customer reverts to spot trade thereafter. Under such a relational arrangement, refunds are honored when the short-run gain from reneging is outweighed by the discounted loss of future surplus from losing the buyback relationship (Baker et al., 2002; Levin, 2003; MacLeod, 2007). This implies that very generous refunds are difficult to sustain because they magnify the temptation to renege in bad states, and that buybacks are more feasible when the relationship has high continuation value—for example, when the supplier is patient and when the relationship generates substantial ongoing rents.

The framework yields four predictions that guide our empirical analysis:

- **Prediction 1: Higher baseline forward trade on buyback links.** Buyback insurance encourages larger orders, raising supplier-to-customer trade in normal times. The higher unit invoice price under buybacks further implies larger forward invoice values.

- **Prediction 2: State-contingent reverse flows in downturns.** Inventory buybacks activate when demand is weak; adverse shocks should therefore generate a spike in customer-to-supplier flows (return of unsold inventory) and a relative decline in forward sales as returns substitute for new purchases.

- **Prediction 3: Concentration in strong, long-lived relationships.** Because the unsold-inventory refund is informal, buybacks should occur (and be honored) where enforcement is feasible: dyads with high continuation value and low fragility.

- **Prediction 4: Capacity–need matching and redeployability.** Buybacks are most valuable for riskier buyers, while honoring requires suppliers with capacity to absorb and redeploy returns; buyback formation should therefore match high-need buyers with high-capacity suppliers, especially where suppliers have stronger outside options to re-market returned goods (Williamson, 1985; Grossman and Hart, 1986).[2]

In Sections 4–7 we operationalize these predictions using VAT invoice flows. Forward sales are supplier-to-customer invoices, and reciprocal sales are customer-to-supplier invoices that, under the institutional accounting treatment of buybacks, correspond to exercising an unsold-inventory return option.

[2]Figure OB2 visualizes how the enforceable region expands with supplier patience and redeployability.

3 Institutional Details

3.1 Informal Buyback Arrangements Across Industries

Inventory buybacks are a common operational response to demand uncertainty. In book publishing, returns from booksellers to publishers are a longstanding practice and are codified in industry guidance.[3] In consumer electronics distribution, downstream resellers often receive protections such as stock-rotation rights, price protection, and return rights for slow-moving inventory.[4] Fashion wholesale frequently relies on sale-or-return terms for seasonal lines, allowing retailers to carry broader assortments and return unsold styles at season end.[5] In industrial/OEM contexts, consignment and sale-on-approval channels embed closely related return options if inventory remains unsold.[6] At the other end of the spectrum, high-value capital goods sometimes feature explicit, option-like repurchase clauses—formal but comparatively rare—such as an Airbus A318 transaction with a specified buyback provision.[7]

While rare, such written clauses may appear in filed contract exhibits or as narrative summaries in annual filings describing vendor terms.[8] In Korea, return rights are sometimes visible through K-IFRS financial statement notes that recognize "refund liabilities" and "right-of-return assets."[9] That said, informal practice is likely central in many settings. Key

[3]See the U.K. Book Industry Communication, "Industry Returns Initiative": `https://bic.org.uk/resources/industry-returns-initiative/`. See also the European and International Booksellers Federation for sector overviews referencing returns practices: `https://europeanbooksellers.eu/press/new-research-paper-book-returns-published-through-eibf-project-rise-bookselling`.

[4]See, e.g., Ingram Micro Inc., *Form 10-K* (discussion of pricing protection, stock-rotation, and return rights in distribution agreements): `https://ir.ingrammicro.com/sec-filings/all-sec-filings/content/0001628280-25-010298/ingm-20241228.htm`.

[5]For trade-press documentation, see *The Business of Fashion*, coverage on wholesale terms and sale-or-return practices (access may require subscription): `https://www.businessoffashion.com`.

[6]U.S. International Trade Administration, guidance on consignment arrangements in international distribution (returns of unsold goods): `https://www.trade.gov` (Trade Finance/Methods of Payment resources).

[7]See Airbus Financial Services–LAN Airlines transaction (repurchase terms): `https://www.sec.gov/Archives/edgar/data/1047716/000119312512146321/d328765dex424.htm`.

[8]For an example of exhibit-style contract language, see an SEC-filed distribution agreement with a PRODUCT RETURN AND STOCK ROTATION" section: `https://www.sec.gov/Archives/edgar/data/918965/000119312514381646/d808869dex101.htm`. For an example of summary disclosure language, see Ingram Micro Inc. *Form 10-K*: `https://ir.ingrammicro.com/sec-filings/all-sec-filings/content/0001628280-25-010298/ingm-20241228.htm`.

[9]For examples of IFRS 15 right-of-return note disclosures, see Samsung Electro-Mechanics (Audit Report; note on "Refund liabilities and right of return assets"): `https://m.samsungsem.com/resources/file/global/ir/archive/2023_Audit_Report.pdf`.

determinants of refundability—product condition, eligibility, timing, and whether inventory is genuinely unsold—are difficult to specify completely and verify at low cost, which limits the practical reach of legal enforcement and elevates the role of repeated interaction, relational capital, and reputational incentives.

3.2 Korea's VAT Invoicing System

South Korea's VAT (Value Added Tax) system provides a unique window to observe these practices at scale. Firms are required to issue electronic VAT invoices for all B2B transactions, and each invoice records the seller and buyer's tax IDs, the date, and two monetary amounts: the VAT-exclusive supply value and the VAT amount charged. Through the VAT input-credit mechanism, firms remit VAT on their value added (output VAT minus input VAT). Because the input credits effectively cancel out the tax paid at prior stages, the government ultimately collects tax only on final sales to consumers.

Crucially, economically similar returns can be recorded differently depending on the underlying transaction. Commercial buybacks of unsold goods are recorded as a new, positive taxable sale in the reverse direction (customer-to-supplier), whereas defect/warranty-related adjustments are recorded as corrections to the original sale (negative entries in the original direction). This institutional feature makes two-way positive flows in a trading relationship a natural revealed-preference signature of buyback arrangements.

4 Data

4.1 Data Sources and Coverage

Our analysis uses confidential VAT invoice records covering nearly all inter-firm transactions in Korea from 2017Q1 through 2021Q4. For each firm in each quarter, we observe its top 50 trading partners by volume. Despite this top-50 cutoff, these records cover on average about 98% of each firm's total purchases and sales, allowing us to map most of the firm-to-firm network. We augment the transaction data with rich firm-level attributes. Using unique tax identifiers, we link each firm to administrative records on its characteristics. From business registration and financial statements, we retrieve information on location, founding year, size (total assets and employment), legal status (incorporation, public listing), whether the firm

is subject to external auditing, and detailed industry classification (5-digit Korean Standard Industrial Classification (KSIC) and primary product categories). Unless noted otherwise, we define *sectors* at the KSIC section level (1-letter code) and *industries* at the KSIC division level (2-digit code). These firm attributes allow us to describe the composition of our sample and to control for heterogeneity across firms in our analysis.

Transaction-level VAT microdata that can be used to map firm-to-firm production networks have become increasingly available for academic research, but thus far remain concentrated in a small set of mostly small and mid-sized economies (OECD, 2025). To our knowledge, this paper is the first to exploit VAT-based firm-to-firm transaction records from Korea, and, as of 2024, Korea is the largest economy for which such VAT transaction data have been used in academic work. By contrast, in very large economies such as the United States, empirical work often infers customer–supplier linkages from partial public disclosures (e.g., major-customer relationships), which are informative but inherently sparse relative to administrative transaction universes (Cohen and Frazzini, 2008; Menzly and Ozbas, 2010). Korea's scale therefore improves external relevance, while its administrative coverage enables tests that are difficult to implement in disclosure-based settings.

4.2 Sample Construction

We construct our sample by first selecting a core set of corporations with continuous activity, excluding sole proprietors that file VAT semiannually. Specifically, we require quarterly VAT presence in at least 70% of quarters from 2017 through 2021, remain active through 2021, and have non-missing total asset data. This filter yields 188,182 core firms spanning all major industries and size groups. We then include every firm that ever appears as a trading partner of one of these core firms during the sample period. This brings in millions of additional firms, 588,746 of which have asset information and are kept in analyses that require firm-level covariates. In total, our dataset comprises nearly 0.7 million unique firms connected by about 120 million trade links. While the regression sample focuses on corporations, coverage extends to many small, privately held businesses that appear anonymously in the VAT data. When computing network variables (e.g., partner counts, partner concentration, and partner-industry concentration), we use the entire VAT universe of trading partners (i.e., millions of

corporations), not only the subset with non-missing assets.[10]

4.3 Identifying Buybacks in Transactions

VAT invoices do not report contract terms or flag returns. We therefore infer inventory buybacks from a revealed-preference signature: strictly positive invoicing in both directions within a firm pair in the pre-COVID window. A *dyad* is an *unordered* firm pair $\langle i, j \rangle$, whereas a *directed flow* is sales $i \to j$. Our buyback indicator is *dyad-level* (does $\langle i, j \rangle$ trade both ways pre-COVID?), whereas our outcomes are *directed* (forward shipments $i \to j$ vs. reciprocal returns $j \to i$). We therefore classify dyads using pre-COVID two-way totals and then analyze directed flows after fixing supplier/customer roles within buyback dyads.

Step 1: Aggregate pre-COVID flows. Let $s_{ij,t} \geq 0$ denote quarterly sales from i to j. Define cumulative pre-COVID sales

$$S_{ij} \equiv \sum_{t \in T^{\text{pre}}} s_{ij,t}, \qquad T^{\text{pre}} = \{t : \text{2017Q1} \leq t \leq \text{2019Q4}\}.$$

Step 2: Classify dyads as buyback vs. non-buyback. Among active pairs ($S_{ij} + S_{ji} > 0$), define the dyad-level indicator

$$\textit{Buyback}_{ij} = \mathbb{1}[S_{ij} > 0 \;\&\; S_{ji} > 0],$$

and $\textit{Buyback}_{ij} = 0$ otherwise. Note $\textit{Buyback}_{ij}$ is symmetric: $\textit{Buyback}_{ij} = \textit{Buyback}_{ji}$.

Step 3: Fix roles to define *forward* and *reciprocal* flows. For buyback dyads, we assign roles using net pre-COVID direction. If $S_{ij} > S_{ji}$, we label i the buyback *supplier* and j the buyback *customer*.[11] Then supplier→customer is the *forward* (shipment) flow and customer→supplier is the *reciprocal* (return) flow.

[10] Under Korean commercial law, larger firms are subject to external auditing and public financial disclosure if they meet at least two of the following four criteria at the end of the prior fiscal year: assets ≥ KRW 12 billion (approximately USD 10 million), liabilities ≥ KRW 7 billion, sales ≥ KRW 10 billion, or ≥ 100 employees. In 2017, 29,263 firms satisfy these thresholds (33,250 firms in 2019); of these, 92.6% are privately held. (Source: Financial Supervisory Service).

[11] Ties $S_{ij} = S_{ji}$ are rare (about one in a million). When they occur, we assign roles randomly.

Step 4: Define firm types and label directed links. A firm is *buyback-active* if it participates in at least one buyback dyad pre-COVID. For each directed link $i \to j$, we assign a three-letter label xyz to every transaction to capture the supplier's firm type (x), the customer's firm type (y), and the transaction type (z) between them. This allows us to distinguish between *buyback dyads* as our treated links and *non-buyback dyads* as our control links:

- $x \in \{b, n\}$ is an indicator that equals b if firm i is involved in any buyback relationship as a supplier and n otherwise;
- $y \in \{b, n\}$ is an indicator that equals b if firm j is involved in any buyback relationship as a customer and n otherwise;
- $z \in \{b, n\}$ indicates is an indicator that equals b if firm i and firm j are directly involved in a buyback relationship and n otherwise.

Because $z = b$ implies both endpoints are buyback-active, the only link type with $z = b$ is *bbb*. The remaining links are non-buyback dyads and serve as controls.

Code	Dyad status	How to read the directed link $i \to j$
bbb	buyback	Both firms are buyback-active and $\{i, j\}$ has a buyback clause. Use Step 3 to interpret $i \to j$ as forward or reciprocal.
bbn	non-buyback	Both firms are buyback-active, but this dyad has no buyback.
bnn	non-buyback	i is buyback-active; j is not; no buyback on $\{i, j\}$.
nbn	non-buyback	i is not buyback-active; j is; no buyback on $\{i, j\}$.
nnn	non-buyback	Neither firm is buyback-active; no buyback on $\{i, j\}$.

All buyback status, role assignment, and link-type labels are constructed using only 2017–2019 data and then held fixed through 2020–2021. Panel A of Figure 1 illustrates the mapping between dyads, directed flows, and the *bbb*/*bbn*/*bnn*/*nbn*/*nnn* labels.

4.4 Validity of the Buyback Proxy

Two-way invoicing is an imperfect proxy: pre-COVID reciprocity could reflect mechanisms other than inventory buybacks (false positives), while true buyback clauses may simply not

be exercised pre-COVID (false negatives).[12] We mitigate and probe these concerns in four ways. First, we exploit VAT accounting treatment to separate defect/warranty adjustments from inventory buybacks. Defect/warranty returns appear as *negative corrections* in the original sale direction, whereas buybacks of unsold goods are recorded as a *new, positive taxable sale* in the reverse direction. We therefore exclude defect/warranty credit notes and require strictly positive invoices in both directions when defining buyback dyads. Second, tightening the definition (e.g., requiring multiple reciprocal pre-COVID quarters) leaves prevalence and coverage nearly unchanged and yields similar DiD estimates. Third, we verify robustness to excluding sectors where routine returns or commercial adjustments are more likely (e.g., electronics and automobiles), and we investigate patterns consistent with opportunism (e.g., channel stuffing) without finding supporting evidence. Finally, we consider alternative sources of two-way invoicing—unrelated cross-purchases, rebates or price-protection settlements recorded as reverse sales, ad hoc distress liquidation, intra-group transfers, or closed-loop reverse logistics (packaging/scrap/byproducts)—and explain why none can jointly match (i) the sharp COVID-timed activation, (ii) the substitution between reciprocal and forward flows, and (iii) the supplier-network redeployment evidence (Internet Appendix Sections OB.2–OB.6). Any remaining misclassification should attenuate estimated treatment effects toward zero, rendering our estimates conservative.

5 Descriptive Evidence

This section presents descriptive patterns that map directly to the four predictions in Section 2. We show that buyback dyads exhibit substantially higher baseline forward trade and invoice values in normal times (Prediction 1), reciprocal flows are infrequent in normal times but surge precisely when demand collapses at COVID-19 (Prediction 2), and buyback-linked relationships are rare by count but concentrated in high-value trading ties (Prediction 3). We also document strong sectoral heterogeneity consistent with buybacks being most relevant where inventory risk and redeployability are salient (Prediction 4).

[12]The most salient false-positive concern is *ordinary two-way trade* in unrelated goods or services (e.g., the customer provides logistics/advertising while buying products). Internet Appendix OB shows that this interpretation is difficult to reconcile with the core signatures predicted by the return-option mechanism: shock-aligned activation at COVID, state-contingent substitution (reverse flows rise as forward flows fall), intermittency in normal times, a strong final-demand gradient, and supplier-side redeployability patterns.

5.1 Prevalence and Network Coverage of Buybacks

Buyback agreements are relatively rare in incidence but large in economic footprint. As Table 1 shows and Section 1 mentions, only about 4.2% of active supplier–customer dyads are classified as buyback dyads, yet these links account for 46.9% of total B2B sales volume (Panel A). Buyback dyads (*bbb*) also generate roughly a quarter of all B2B invoices, indicating that buybacks are concentrated among the highest-volume trading pairs. Nearly half of firms (46.0%) participate in at least one *bbb* (as a supplier, a customer, or both), and conditional on having a buyback partner, firms route a meaningful share of their activity through these ties: the median firm realizes about 30% of total sales (and a similar share of purchases) via *bbb* (Table 1, Panel A). As a result, the implied risk-sharing network is extensive: less than 2% of total trade value occurs entirely outside the buyback system (Panel B), i.e., between firms that are both disconnected from buyback-linked relationships.

Consistent with the state-contingent nature of buybacks (Prediction 2), buyback clauses are not exercised continuously in normal times. Consistent with Prediction 2 that buybacks act as a *contingent* backstop, buyback clauses are not exercised continuously in normal times. In the 12-quarter pre-COVID period, the median *bbb* dyad records reciprocal flows in 4 of 12 quarters (mean 5.6), and the median return share (the fraction of total dyad trade value flowing from customer back to supplier) is 11.5% (Table 1, Panel C). Even at the 75$^{\text{th}}$ (90$^{\text{th}}$) percentile, the return share is 26.1% (38.9%). Returns account for a larger share of invoice *counts* than of invoice *value* (median of about one-third of invoices versus one-eighth of value), implying that reverse-direction shipments tend to be smaller on average than forward shipments. Together, these patterns fit the interpretation of buybacks as insurance that is triggered intermittently rather than as routine two-way procurement.

These prevalence and intensity facts are robust to alternative buyback definitions. Panel D of Table 1 shows that requiring stricter pre-COVID evidence of reciprocity (e.g., at least two reciprocal quarters rather than one) has essentially no effect on prevalence or coverage. Even under a much tighter definition (e.g., restricting to dyads where at least 10% of total trade value is returned), about 2.3% of links still qualify and they account for roughly 21.8% of total B2B volume. Thus, whether defined broadly or narrowly, buybacks constitute a small but economically central set of links through which reverse flows occur.

Buyback prevalence also varies sharply across sectors in a way consistent with Prediction 4. Buybacks are far more common in goods-producing and distribution sectors than

in services: manufacturing and wholesale/retail exhibit buyback incidence around 4–5% of links, several times higher than most other industries (Table 2, Panel A), and buyback links mediate a large share of their trade (e.g., over half of manufacturing output and 41.7% of wholesale/retail sales). On the buying side, wholesalers and retailers are especially intensive users: they have buyback arrangements with 6.7% of their suppliers and those links cover nearly 50% of procurement value (Table 2, Panel B). In contrast, buybacks are close to absent in sectors where unsold-inventory risk is limited or where returns are more naturally handled through contractible adjustments (e.g., Real Estate, Education, Public Administration). Figure 2 summarizes these patterns in a sector-by-sector heat map of buyback prevalence.

5.2 Sales Flows in Buyback and Non-Buyback Dyads

Figure 3 plots quarterly sales flows for dyads with and without pre-COVID buyback agreements. The top panels show forward (supplier-to-customer) flows. The bottom panels show reciprocal (customer-to-supplier) flows for *bbb* dyads; for non-buyback dyads, reciprocal flows are zero by construction, so we re-plot their forward flows for scale and comparability.[13] Two patterns speak directly to the model predictions. First, buyback dyads (*bbb*) exhibit substantially higher forward trade than non-buyback dyads (*bbn*, *bnn*, *nbn*, *nnn*) throughout the pre-pandemic period, consistent with Prediction 1 that buyback insurance supports larger baseline orders and higher invoice values. Second, when COVID-19 hits in 2020, reciprocal flows spike sharply for buyback dyads while remaining flat for controls, consistent with Prediction 2 that non-verifiable unsold-inventory buybacks activate in bad demand states.[14] As discussed in Internet Appendix Section OA.6, our buyback measure is based on *positive* reverse-direction invoices and therefore aligns with the non-verifiable, state-contingent buyback component rather than verifiable defect/warranty credit notes. Finally, all series rise post-2020 in Figure 3, but this is partly mechanical because the plot conditions on surviving, active dyads. In the full sample including inactive links (zeros), average trade volumes fall.[15]

[13] Buyback and non-buyback links correspond to the blue and red series in Figure 1 (Panel B for suppliers and Panel C for customers).

[14] Figure OB1 shows that the post-2020 spike in reciprocal flows is broad-based across sectors rather than driven by a single industry.

[15] The dip in non-buyback forward sales in 2020Q1 mirrors a similar first-quarter drop in 2019, indicating seasonality. Over the full year 2020, non-buyback forward sales are essentially flat relative to 2019.

5.3 Buybacks and Pre-Shock Order Quantities

A central implication of the framework is that buybacks raise baseline procurement on two margins (Prediction 1 in Section 2). First, by capping the buyer's downside in weak-demand states, the buyback clause induces the customer to commit to more inventory ex ante. Second, under the benchmark in which the buyback premium prices the supplier's expected refund liability, the unit invoice price is higher in buyback relationships. Together, the model predicts larger forward trade in normal times both because orders are larger or more frequent and because each order is invoiced at a higher price. We operationalize these two channels using the number of forward invoices (order frequency) and forward sales per invoice (average order value).

Table 4 implements this test in the pre-pandemic cross section. We regress 2019 dyad outcomes on a *Buyback* indicator, adding progressively richer fixed effects. Columns 1–3 use log(1 + Forward Invoices), and Columns 4–6 use log(1 + Forward Sales per Invoice). Across specifications, *Buyback* is positive ($p < 0.01$) and economically large. In the most saturated specification with customer and supplier fixed effects (Column 3), buyback dyads have about 35% more forward invoices than non-buyback dyads, consistent with higher baseline ordering. Column 6 shows that forward sales per invoice are about 178% larger in buyback dyads, consistent with the buyback premium (and potentially larger shipment size per order) raising average invoice values.[16] While these cross-sectional patterns reflect both selection and the insurance mechanism, they provide a natural benchmark; Section 7 then exploits the COVID shock to identify state-contingent activation and substitution between forward and reverse flows (Prediction 2).

6 Empirical Strategy and Identification

6.1 COVID-19 as a Quasi-natural Shock

We exploit the onset of the COVID-19 pandemic as a large, sudden, and plausibly exogenous collapse in final demand to identify the state-contingent effects of inventory buyback arrange-

[16] To gauge magnitudes, the median trading pair issues about five forward invoices per year (pre-COVID). A 35% increase corresponds to roughly two additional invoices annually. Median annual forward sales per dyad are about 8.7 million KRW, implying a typical invoice size around 1.7 million KRW; a 178% increase implies an average invoice size about 2.8 times larger (roughly 4.7 million KRW versus 1.7 million KRW).

ments. While COVID-19 can in principle generate both demand- and supply-side disruptions, South Korea provides a relatively clean setting to study a sharp demand contraction.[17] Korea's containment strategy relied heavily on testing, contact tracing, and targeted isolation measures rather than prolonged economy-wide shutdowns, and broad mandated stoppages of production activity were comparatively limited Aum et al. (2021). As a result, the onset of COVID-19 in Korea is well-suited to serve as a negative final-demand shock that increases the value of inventory return options, especially in consumer-facing supply chains.

Our empirical design is a DiD framework (e.g., Angrist and Pischke, 2009; Imbens and Wooldridge, 2009) that compares dyads with a pre-pandemic buyback arrangement (treated dyads) to observationally similar dyads without such an arrangement (control dyads) before versus after COVID-19. The-pre period is 2017Q1–2019Q4 and the post-period is 2020Q1–2021Q4.

We estimate:

$$Y_{ij,t} = \beta \, Buyback_{ij} \times Post_t + \alpha_{ij} + \gamma_{i,t} + \delta_{j,t} + \varepsilon_{ij,t}, \tag{1}$$

where $Y_{ij,t}$ is a dyad-level outcome for $\langle i, j \rangle$ (e.g., forward sales from supplier i to customer j, or reciprocal sales from j to i), $Buyback_{ij}$ indicates whether the dyad is governed by a buyback arrangement based on pre-COVID information, and $Post_t$ equals one in 2020–2021. The coefficient β captures the differential post-shock change for buyback dyads relative to non-buyback dyads.

A central endogeneity concern is selection into buybacks: dyads that adopt buybacks may differ systematically (relationship strength, product characteristics, inventory-risk profiles). We address this with a high-dimensional fixed-effects structure. Dyad fixed effects α_{ij} absorb time-invariant match heterogeneity (e.g., baseline trade intensity, persistent relationship quality, product fit). Supplier×year fixed effects $\gamma_{i,t}$ and customer×year fixed effects $\delta_{j,t}$ absorb time-varying firm-level shocks on each side of the relationship (e.g., overall demand collapse, liquidity shocks, capacity disruptions, sectoral exposure). Identification therefore comes from within-dyad changes at COVID-19 net of shocks common to a given

[17] See, e.g., Guerrieri et al. (2022b) and Baqaee and Farhi (2022) for frameworks in which pandemic-related supply shocks and demand contractions interact, and Brinca et al. (2021) for sector-level empirical decompositions. We benchmark cross-country policy restrictiveness using the Oxford COVID-19 Government Response Tracker (OxCGRT) Stringency Index (Hale et al., 2021).

supplier-year (across all customers) or customer-year (across all suppliers). Standard errors are two-way clustered by supplier and customer (Cameron et al., 2011).

To further tighten the counterfactual, we also implement one-side (focal-firm) comparisons. In supplier-focused (customer-focused) tests, we restrict attention to dyads where the supplier (customer) is buyback-active and compare its buyback links (*bbb*) to its own non-buyback links (*bbn* and *bnn*). These within-firm comparisons reduce sensitivity to cross-firm differences in buyback propensity or COVID exposure.

Finally, to limit reverse causality and post-shock renegotiation, we define buyback status using only pre-COVID information and hold it fixed through 2020–2021, so post-2020 outcomes cannot mechanically affect treatment assignment.

6.2 Entropy Balancing and Parallel Trend Diagnostics

Because buyback dyads are rare but economically large and embedded in more durable relationships, treated and untreated dyads can differ markedly along multiple dimensions, making conventional matching approaches fragile and prone to trimming (e.g., Rosenbaum and Rubin, 1983; Stuart, 2010; King and Nielsen, 2019). We therefore use entropy balancing to preprocess the control group, reweighting non-buyback dyads so that they match buyback dyads on a rich set of pre-COVID characteristics (Hainmueller, 2012).[18] We balance on dyad attributes (e.g., distance and relationship depth), supplier and customer characteristics (e.g., size and balance-sheet variables), supplier and customer industry indicators, and pre-COVID changes in the outcome. Balancing on pre-shock outcome changes is particularly valuable in a DiD design because it directly targets differential pre-trends and reduces model dependence (see also Abadie, 2005; Heckman et al., 1997).

We assess the parallel-trends assumption with an event-study specification with leads and lags (e.g., Autor, 2003). After entropy balancing, covariate balance is tight (Tables 5 and OB1),[19] and treated and reweighted control dyads track closely before 2020: lead coefficients are small and statistically indistinguishable from zero, while coefficients diverge sharply beginning in 2020 (Figure 4).

[18]Entropy balancing chooses nonnegative weights on controls to satisfy exact balance constraints on selected covariate moments (here, means) while minimizing information loss relative to uniform weights.

[19]Entropy balancing is conducted twice: first between forward buyback dyads (*bbb*) and non-buyback dyads (*bbn*, *bnn*, *nbn*, *nnn*) in Table 5, and second between reciprocal buyback dyads (backward *bbb*) and the same control group in Table OB1.

6.3 Remaining Identification Threats

Dyad-specific shocks. Even with dyad and firm×year fixed effects, unobserved match-specific shocks around 2020 could differentially affect buyback versus non-buyback dyads. We mitigate this concern by fixing treatment status out of sample (pre-COVID), absorbing all supplier-year and customer-year shocks, and reporting robustness across alternative control sets, including within-firm comparisons that benchmark *bbb* dyads against other links of the same buyback-active firms.

Survivorship and sample selection. Our dyad-level DiD focuses on relationships observed both before and after COVID-19 to ensure well-defined within-dyad changes, and our firm-level filters require sufficiently continuous VAT activity and survival through 2021. If fragile non-buyback links are more likely to dissolve during the pandemic, conditioning on survival makes the control group mechanically more resilient and can attenuate estimated effects. We therefore interpret our baseline estimates as intensive-margin effects within continuing relationships and as a lower bound on the full insurance value once extensive-margin adjustments (relationship dissolution and firm exit) are included.

Proxy-based buyback identification. Because VAT invoices do not label contract terms, our buyback indicator is proxy-based: we classify a dyad as a buyback relationship if it exhibits strictly positive two-way trade in the pre-COVID window. This may generate false positives (two-way trade for reasons unrelated to buybacks) or false negatives (a buyback clause not exercised pre-COVID). We address these concerns by distinguishing defect/warranty credit notes (negative corrections) from reverse-direction positive sales, tightening the buyback definition (e.g., requiring multiple reciprocal quarters), and excluding sectors where routine returns are more prevalent. Any remaining misclassification should attenuate β toward zero by blurring treated and control groups, making our estimates conservative.

7 Impact of Buybacks during COVID-19

7.1 Buybacks as Insurance during COVID-19

Panel A of Table 6 shows that buybacks provide state-contingent insurance during COVID-19, mirroring the spike in reciprocal flows in the bottom panels of Figure 3. Guided by the VAT accounting in Appendix OB, we interpret *positive* customer-to-supplier invoices

as exercised inventory buybacks (unsold goods repurchased), rather than defect/warranty adjustments that appear as negative corrections in the original direction. In our DiD design (Section 6), treatment status and dyad roles are fixed using only pre-COVID data, so the post-2020 reversal in flow direction reflects activation of a pre-existing arrangement rather than reclassification.

The estimated treatment effect β is large for return flows (Column 1): buyback dyads (*bbb*) exhibit a 10.4% increase in upstream (customer→supplier) sales in 2020–2021 relative to entropy-balanced non-buyback dyads (*bbn*, *bnn*, *nbn*, *nnn*). At the same time, forward sales along buyback links fall by an additional 3.7% (Column 5), consistent with downstream firms partially substituting from new orders toward returns when demand collapses.[20] Both effects are statistically significant ($p < 0.01$) and align with the model's risk-sharing implication that buybacks activate in adverse states (Section 2).

These findings are robust to tighter identification and alternative control sets. Comparing *bbb* links to the same firms' non-buyback links (*bbn*, *bnn*) within a year (Columns 2 and 6), we include supplier×year and buyer×year fixed effects so that only within-firm-year variation identifies β; the estimates are nearly unchanged.[21] For completeness, we also benchmark *bbb* dyads against dyads of non-buyback firms (*nbn* and *nnn* in Columns 3 and 7; *nnn* in Columns 4 and 8). Because these specifications have a much smaller control pool (Table 1, Panel C), we replace firm-year fixed effects with industry-year fixed effects; magnitudes attenuate but the sign and statistical significance of β remain. Overall, buybacks materially reshape trade during the shock: higher return flows and lower forward flows than comparable controls. Since the sample conditions on surviving relationships (Section 6), the estimates likely understate the full insurance value.

Internet Appendix Table OB2 re-estimates our baseline DiD (Panel A, Columns 1 and 5) under a broad set of alternatives and reaches the same conclusion. The post-COVID effects remain when we use sales per invoice instead of total sales, tighten the buyback definition (e.g., requiring at least two pre-COVID reciprocal quarters), drop entropy-balancing weights, or exclude industries with routine defect/warranty returns (electronics, automobiles). Un-

[20] This substitution relaxes the buyer's cash outlay at a rate equal to the differential between the wholesale price under a buyback agreement and the unit refund price, $w_b - b$, as in Section OA.

[21] With partner-year fixed effects, identification comes from within-firm-year contrasts across dyad types (Figure 1). Because partners' own buyback dyads are excluded by construction, many remaining partner non-buyback dyads are singletons within a partner-year and are absorbed by the fixed effects.

reported checks using log invoice counts or estimating Equation 1 at a quarterly frequency yield similar qualitative patterns.

7.2 Reallocation of Risk and Output

We next ask where the returned goods go. If buybacks merely push losses upstream, suppliers should see an unambiguous contraction in output. If, instead, suppliers can *redeploy* returned inventory through other outlets—as in the model's redeployability channel—then the decline in shipments within *bbb* dyads should be partly offset by expansions on the supplier's other links.

Panel B of Table 6 provides evidence consistent with active redeployment. We broaden the treatment from buyback dyads to *all* forward links of buyback-active suppliers (i.e., *bbb* plus their non-buyback links *bbn* and *bnn*) and re-estimate Equation 1. To keep the comparison aligned with Panel A's cross-firm benchmarks, we use industry×year fixed effects as in Panel A, Columns 3–4 and 7–8, so coefficients are directly comparable. Relative to Panel A, both the post-COVID increase in the reciprocal-flow outcome and the decline in forward sales are attenuated. The smaller reverse-flow effect (Panel B, Column 1 vs. Panel A, Column 3) is consistent with the demand shock depressing forward sales on the non-buyback links that now enter the treated set. More importantly, the weaker decline in forward sales (Panel B, Column 2 vs. Panel A, Column 7) suggests a compensating margin: the reduction in shipments along *bbb* links is partially offset by increased shipments to other customers via *bbn*/*bnn* links, consistent with suppliers reallocating inventory bought back from buyback customers.

Figure 5 corroborates this network-reallocation mechanism using dyad-type shares that are fixed by the pre-COVID classification (Section 6). At the onset of the pandemic, the trade share routed through *bbb* links falls, while the share routed through *bbn* links rises in *value* but not in *count*, indicating an intensive-margin expansion along existing non-buyback ties. By 2021, the *bbn* share increases in both value and count, consistent with a subsequent extensive-margin adjustment as new *bbn* outlets form. Meanwhile, dyads between purely non-buyback firms (*nnn*) do not gain share. Taken together, Panel B of Table 6 and Figure 5 imply that buybacks do more than simply reallocate losses upstream: upstream firms actively redeploy returned goods—first by scaling up shipments through existing non-buyback relationships

and then by expanding their customer base—thereby stabilizing forward sales beyond the original buyback dyads.

7.3 Heterogeneous Effects by Consumer Exposure and Sector

The model predicts that the buyback option is exercised most intensely when the downstream side is most exposed to final demand risk. Table 7 supports this prediction. Column 1 augments Equation 1 by interacting $Post \times Buyback$ with *High B2C*, an indicator equal to one when the customer's pre-COVID business-to-consumer (B2C) sales share (B2C share = (total sales − B2B sales)/(total sales)) is above the sample median. The baseline $Post \times Buyback$ coefficient is 0.095 ($p < 0.01$), and the incremental effect for high-B2C customers is 0.059 ($p < 0.01$), implying a total post-COVID increase of about 0.154 log points in reciprocal flows for high-B2C buyback links relative to entropy-balanced controls. Thus, buybacks activate most strongly precisely where the COVID demand shock translates most directly into unsold inventory, consistent with customers exercising the return option to shed inventory risk upstream in bad states.

Columns 2–5 show a pronounced sector gradient in the same outcome, consistent with the geography of the demand collapse and the feasibility of redeployment. Reciprocal flows rise most in retail (0.259; $p < 0.01$), followed by wholesale (0.187; $p < 0.01$), then manufacturing (0.100; $p < 0.01$); effects are small in the residual sectors (0.037; $p < 0.10$). This ordering matches the idea that inventory risk is most acute closest to the consumer and that buyback-linked relationships are especially prevalent in manufacturing–distribution chains (Table 2). More broadly, the pattern is consistent with buybacks delivering the largest insurance value in sectors where idiosyncratic demand shortfalls are sharp and where upstream firms can more readily take goods back and re-market them.

These gradients also dovetail with the reallocation results in Section 7.2. There we show that suppliers absorb returns and stabilize output by redirecting shipments through their other customer links—first by expanding along existing ties (intensive margin) and later by forming new outlets (extensive margin). Large retail and wholesale coefficients therefore naturally reflect bulk returns originating near final demand, while the smaller manufacturing coefficient is consistent with a greater share of adjustment occurring through upstream redeployment across the supplier's broader network rather than as persistent, dyad-

level reciprocal spikes.

7.4 Determinants of Buyback Formation

Our framework treats inventory buybacks as informal, state-contingent insurance sustained by relational incentives (Section 2). Two predictions guide the formation tests. First, if the refund promise is self-enforcing, buybacks should concentrate in high-continuation-value relationships (Prediction 3). Second, formation should exhibit capacity–need matching: riskier downstream firms value the embedded put option more, while buybacks are feasible only with upstream firms that can absorb and redeploy returns (Prediction 4).

Table 8 supports both predictions. Panel A shows that buybacks are more likely in dyads with stronger relational-capital proxies. Across all specifications—unconditional on industry fixed effects (Column 1), conditional on industry-level fixed effects (Column 2), and most stringently, firm-level fixed effects (Column 3)—buybacks are more prevalent in geographically closer pairs (log distance loads negatively; $p < 0.01$) and in relationships that are both long-lived and uninterrupted (log total transacting quarters and log consecutive transacting quarters load positively; $p < 0.01$). The prominence of uninterrupted depth is consistent with the enforcement logic: buybacks are most credible where repeated interaction makes deviation costly and coordination frictions are low.

Panel B then provides direct evidence of capacity–need matching. Buyback customers are observably riskier ex ante: sales-growth volatility loads positively ($p < 0.01$) for buyback customers (Columns 1–2). In contrast, buyback suppliers are more stable: supplier sales-growth volatility loads negatively (Columns 3–4).[22] At the same time, suppliers that participate as buyback insurers operate with substantially broader trading networks: the coefficient on log unique partners is positive ($p < 0.01$) for both sides but is roughly twice as large for buyback suppliers as for buyback customers. In the model, a wide downstream outlet base raises redeployability and relaxes the self-enforcement constraint; empirically, this pattern dovetails with the network-level redeployment evidence in Section 7.2.

Beyond these core implications, Table 8 reveals systematic correlates of buyback adoption that reinforce a risk-management interpretation. Both buyback customers and buyback suppliers are larger (log assets loads positively) and more levered (debt/assets loads posi-

[22]With industry fixed effects, the magnitude (and significance) attenuate from -0.41 ($p < 0.01$) to -0.26 ($p < 0.10$) percentage points, suggesting that part of the stability advantage reflects industry composition.

tively), consistent with stronger incentives to hedge when financing frictions or distress costs are salient (Smith and Stulz, 1985; Froot et al., 1993). Buyback users also appear younger on average (log firm age and log CEO age load negatively), and they are less profitable ex ante (return on assets (ROA) loads negatively for both sides), suggesting that buybacks are used disproportionately by firms for whom cash-flow risk is particularly costly. Finally, innovation proxies load positively at formation: R&D intensity is positive for both sides, and patenting is especially strongly associated with buyback customers (Panel B). To the extent that innovative firms rely more on intangible capital and face tighter collateral constraints, these correlates are consistent with substitution toward relational, product-market hedges when standardized financial hedges are limited or costly (Rampini et al., 2014).

7.5 Relational Enforcement: Honoring of Buyback Agreements

Formation alone does not guarantee insurance. Because the refund is non-verifiable and therefore informal, the model predicts that performance in adverse states hinges on relational capital and supplier capacity and redeployability (Section 2). We therefore study which pre-COVID buyback relationships are actually *honored* when COVID-19 hits. Following Table 9, we define a buyback dyad as honored if its COVID-period reciprocal sales exceed its pre-COVID baseline (results are robust to higher thresholds), and we relate honoring to the same pre-COVID dyad- and firm-level covariates used in Table 8. Focusing on honoring also mitigates concerns that our proxy picks up dormant clauses that were never exercised.

Panel A of Table 9 shows that honoring is tightly linked to relationship strength, consistent with Prediction 3. The largest and most robust predictor is uninterrupted relationship depth: log consecutive transacting quarters enters strongly positively ($p < 0.01$) across all specifications, including with customer and supplier fixed effects (Columns 1–3). Geographic proximity also matters: log distance loads negatively ($p < 0.01$) in all columns. In contrast, cumulative relationship length (log transacting quarters) adds little once continuity is controlled for in Columns 1–2, but becomes economically important in the within-firm specification (Column 3), where identification comes from comparing a firm's buyback dyads with differing relationship histories. Overall, these patterns match the self-enforcement logic: buybacks are most likely to be honored where the shadow of future trade is strongest and coordination frictions are lowest.

Panel B of Table 9 then isolates the supplier-side capacity margin emphasized by Prediction 4. Suppliers that honor at least one buyback agreement during COVID are larger (log assets loads positively), more stable (sales-growth volatility loads negatively), and operationally stronger (ROA and asset turnover loads positively) (all $p < 0.01$ except ROA with $p < 0.05$ in Column 2). These capacity proxies remain significant with industry fixed effects, indicating that honoring is not simply a sector composition effect. By contrast, innovation-oriented characteristics are not what predicts performance in the crisis: R&D intensity is negatively associated with honoring ($p < 0.01$), and patenting is not significant. This contrast with Table 8 suggests that while innovative firms are more likely to adopt buybacks ex ante, honoring in a severe downturn is ultimately governed by short-run liquidity and operational capacity rather than long-horizon orientation.

Finally, the network variables point to a two-sided enforcement mechanism—*ability* to redeploy returns and *incentives* to honor an informal promise. In Table 9, Panel B, honoring is more likely for suppliers with broader networks (log unique partners loads positively; $p < 0.01$), consistent with the redeployability channel: suppliers with more downstream outlets can more easily place returned inventory, echoing the reallocation patterns in Section 7.2 and the outside-option logic in Section 2. At the same time, honoring is also more likely when a supplier's trade is more concentrated (higher partner HHI and partner (2-digit) industry HHI; $p < 0.01$). This contrasts with formation, where buyback suppliers are less concentrated across counterparties (partner HHI loads negatively in Table 8, Panel B). A natural interpretation is relational stakes: when a small set of downstream relationships accounts for a large share of the supplier's rents, reneging is more costly because it jeopardizes valuable future trade. Taken together, the network evidence implies that buybacks provide effective insurance precisely when the supplier both *can* take back and redeploy inventory and *has incentives* to preserve the relationships that sustain the informal agreement.

8 Conclusion

We study whether informal inventory buyback agreements provide risk sharing in supply chains, using an economy-wide panel of Korean VAT invoices and the COVID-19 demand collapse as a stress test. Identified via pre-pandemic reciprocal invoicing, buyback links are rare by count but economically central. In an entropy-balanced DiD design, buyback

links activate sharply when COVID-19 hits: reciprocal sales rise and forward sales fall relative to comparable non-buyback dyads, consistent with customers exercising a buyback option and substituting away from new orders. Suppliers do not simply warehouse the shock; they redeploy returned goods through other customer links, helping stabilize shipments beyond the original buyback dyads. The effects are largest where exposure to final demand is greatest and in consumer-facing sectors. Formation and performance align with the relational-contract mechanism: buybacks concentrate in close, durable relationships, reflect capacity–need matching, and are honored under stress primarily by high-capacity suppliers.

These findings imply that decentralized, relationship-based contracting can act as a meaningful operational hedge. Policies that preserve working-capital capacity at upstream insurer firms during crises—and tools that use invoice data to monitor where returns accumulate and where redeployment capacity is tight—can help sustain this private risk-sharing margin and improve supply-chain resilience.

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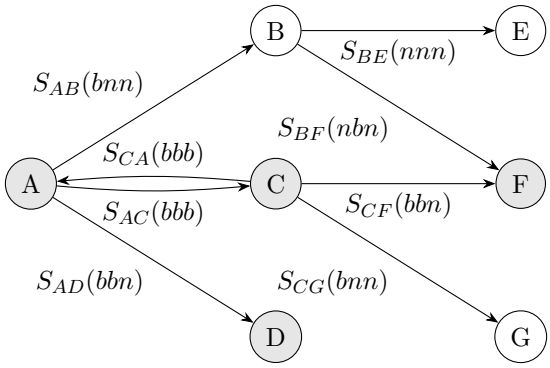
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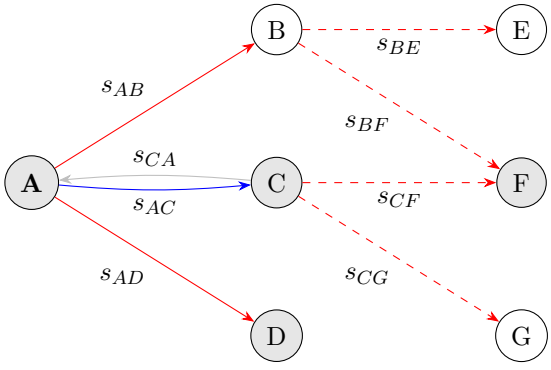
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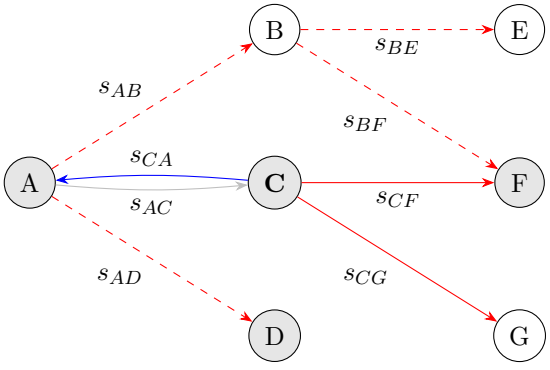
Figure 1: Identifying buyback agreements and defining treated vs. control dyads.
The figure formalizes our classification using pre-COVID data (2017Q1–2019Q4). Nodes are firms. Directed edges are sales. Let $s_{ij,t} \geq 0$ denote quarterly sales from firm i to firm j in quarter t, and $S_{ij} \equiv \sum_{t=\mathcal{T}^{pre}} s_{ij,t}$ the pre-COVID cumulative flow, where $\mathcal{T}^{pre} = \{t : 2017Q1 \leq t \leq 2019Q4\}$. Among active dyads ($\max[S_{ij}, S_{ji}] > 0$), $\langle i, j \rangle$ is a buyback dyad if $\min[S_{ij}, S_{ji}] > 0$ and a non-buyback dyad otherwise. For buyback dyads, roles are fixed by totals: if $S_{ij} > S_{ji}$, i is the supplier and j the customer. Each directed link is labeled $S_{ij}(xyz)$, where x and y indicate whether i and j are buyback-active (b) or not (n); z indicates whether $\langle i, j \rangle$ is governed by a buyback agreement (b) or not (n). This yields five dyad types (*bbb*, *bbn*, *bnn*, *nbn*, *nnn*); for *bbb* we distinguish forward vs. reciprocal sales. Firms with any *bbb* link are buyback-active (gray), and others are non-buyback (white). Panel A illustrates the definitions on a small pre-COVID network. Panels B and C show the research design for forward sales and reciprocal sales, respectively. In each, the blue (*bbb*) edge is treated, red edges are controls, and gray edges are excluded. Dashed control edges are auxiliary counterfactuals not required to identify buyback dyads.



A. Buyback vs. non-buyback dyads ($S_{AC} > S_{CA} \Rightarrow$ A: Supplier, C: Customer)



B. Treated vs. control dyads for suppliers



C. Treated vs. control dyads for customers

Figure 2: Inter-industry buyback prevalence heat map.
The heat map displays a matrix of supplier (rows) × customer (columns) industry sales using pre-COVID data (2017Q1-2019Q4). Each cell shows buyback intensity: the share of observed supplier-customer links in that industry pair that are buyback dyads (Figure 1). Darker cells indicate greater prevalence. Industries are coded using the 2-digit Korean Standard Industrial Classification.

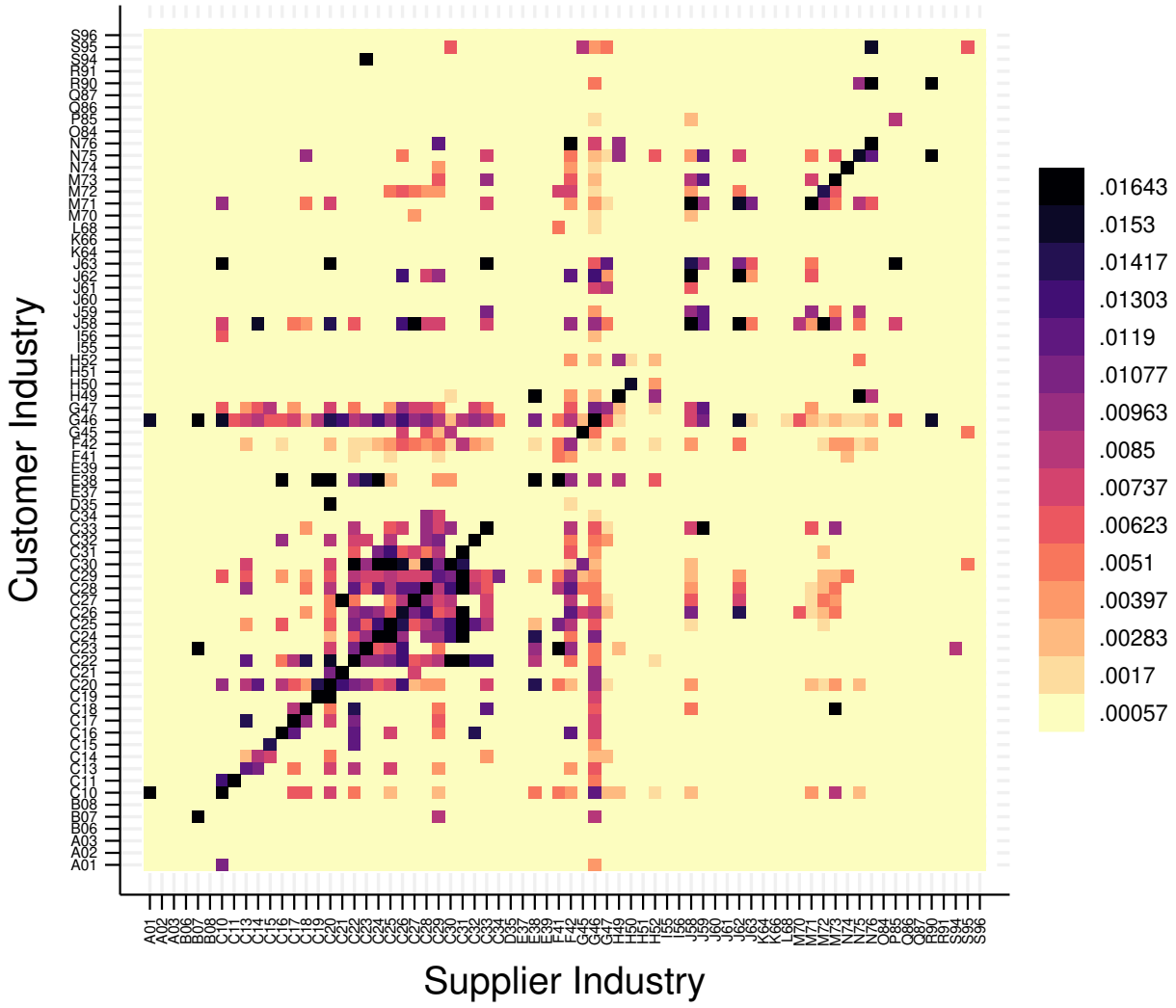


Figure 3: Sales flows in buyback vs. non-buyback dyads.
This figure plots quarterly dyad-level means of sales invoice counts and VAT-exclusive values (KRW millions) for 2017Q1-2021Q4. Buyback (blue) and non-buyback (red) dyads follow the pre-COVID classification in Figure 1. For buyback dyads, supplier and customer roles are set by pre-COVID net flows and held fixed through 2021. The top row plots forward flows (supplier to customer). The bottom row plots reciprocal flows (customer to supplier) for buyback dyads; for non-buyback dyads, reciprocal flows are zero by construction, so forward flows are shown for comparison. The left column reports counts and the right column reports values. The vertical dashed line marks 2019Q4, the last pre-COVID quarter.

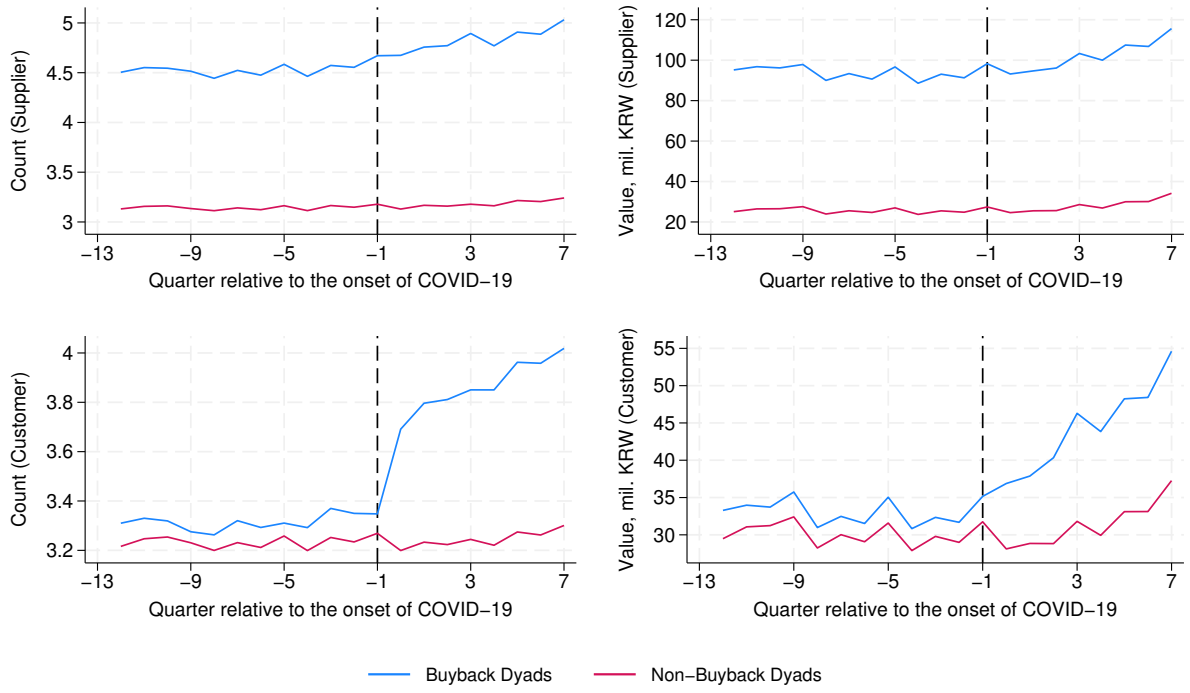
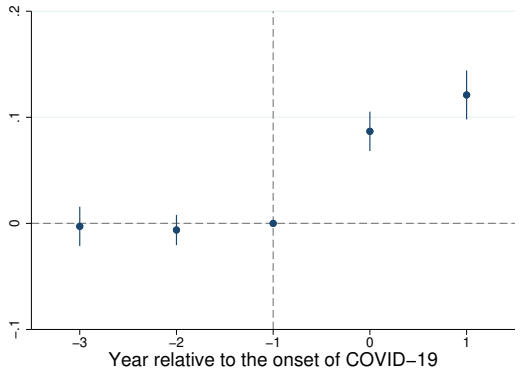
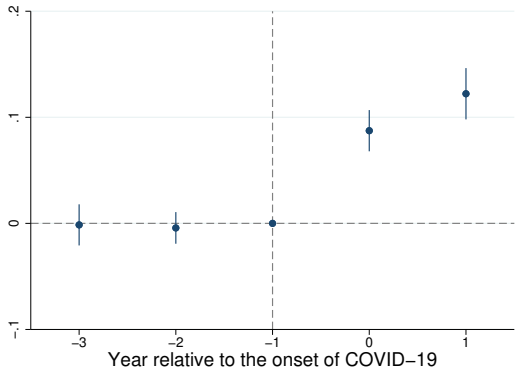


Figure 4: Parallel trends after entropy balancing.
Each panel plots event-study coefficients with 95% confidence intervals from dyad-level regressions of outcomes on *Buyback*× year indicators for 2017-2021 (2019 is omitted; vertical dashed line). *Buyback* equals one for buyback dyads (Figure 1). Panels A-B plot *Log Reciprocal Sales*; Panels C-D plot *Log Forward Sales*. Forward sales are VAT-exclusive supplier-to-customer values. Reciprocal sales are VAT-exclusive customer-to-supplier values for buyback links; for non-buyback links with zero reciprocal sales, the outcome is set to forward sales for comparability. All models include dyad fixed effects as well as customer×year and supplier×year fixed effects. Standard errors are two-way clustered by supplier and customer. Control (non-buyback) dyads are reweighted to treated means via entropy balancing on pre-COVID covariates (see Tables 5 and OB1). Control composition varies by panel: A and C use *bbn*, *bnn*, *nbn*, *nnn* and B and D use *bbn* and *bnn* (Figure 1). The sample is restricted to dyads active in both the pre-COVID (2017-2019) and COVID (2020-2021) periods to preserve pre-COVID balance at the cost of survivorship bias.

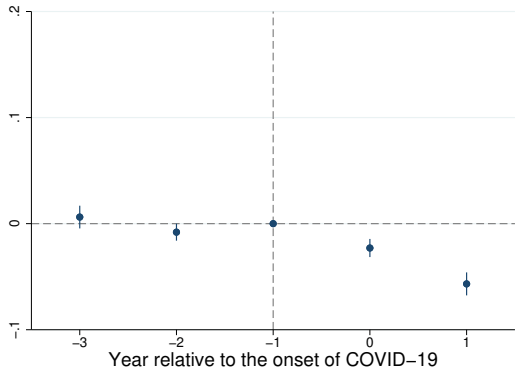
A. Log Reciprocal Sales
(*bbb* vs. *bbn/bnn/nbn/nnn*)



B. Log Reciprocal Sales
(*bbb* vs. *bbn/bnn*)



C. Log Forward Sales
(*bbb* vs. *bbn/bnn/nbn/nnn*)



D. Log Forward Sales
(*bbb* vs. *bbn/bnn*)

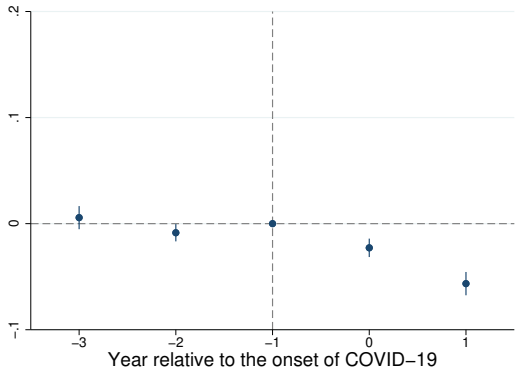
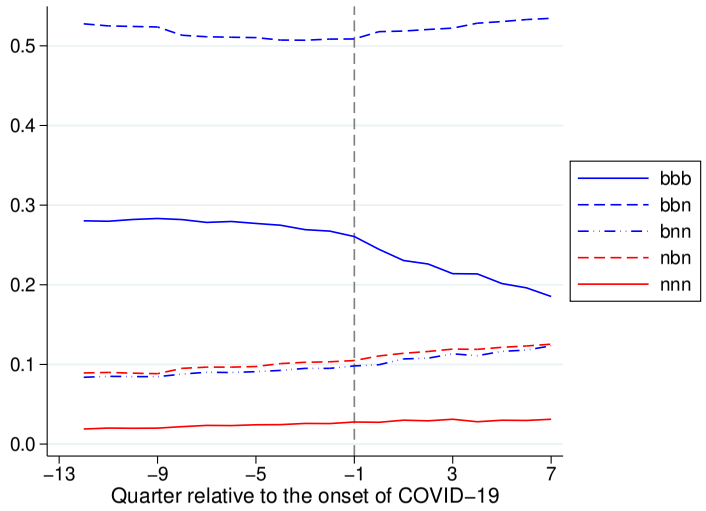


Figure 5: Trends in dyad-type shares around COVID-19.
This figure displays quarterly shares of total transaction value (Panel A) and active supplier-customer dyads (Panel B) for 2017Q1-2021Q4. Dyad types (bbb, bbn, bnn, nbn, nnn) are set in the pre-COVID window (2017Q1-2019Q4) and held fixed through 2021Q4 (Figure 1). Blue lines denote dyads of buyback-active firms and red lines denote dyads of non-buyback firms. The x-axis shows quarters relative to the onset of COVID-19 (2020Q1).

A. Share of Transaction Value



B. Share of Active Dyads

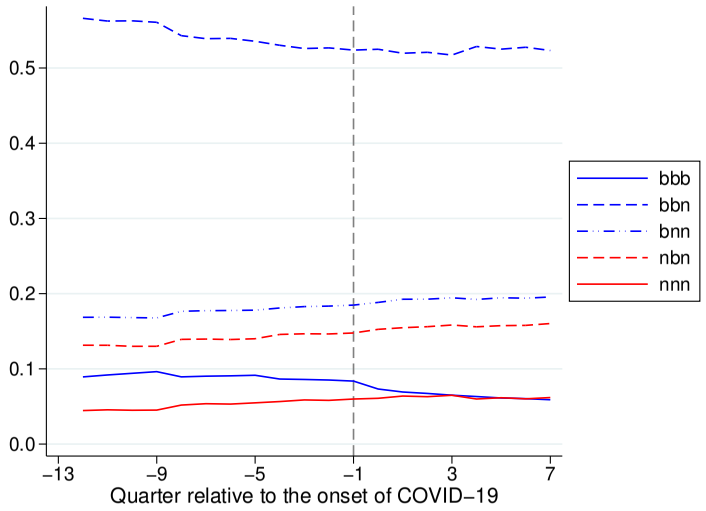


Table 1: Prevalence, intensity, and network roles of buybacks

The table provides summary statistics from pre-COVID VAT invoices (2017Q1-2019Q4). Panel A reports the share of active supplier-customer links that are buyback dyads (Figure 1), the shares of sales and invoices mediated by buybacks, the share of firms with at least one buyback partner (as supplier, customer, or both), and medians for the number of buyback partners and exposure to buyback partners (sales and purchases). Panel B reports the distribution of the return share (customer-to-supplier sales divided by total dyad trade pre-COVID), the mean and median numbers of quarters with positive two-way flows among buyback dyads, and the median share of forward (supplier-to-customer) sales and invoices. Panel C describes network roles and partition trade into five link types (Figure 1) – *bbb*, *bbn*, *bnn*, *nbn*, *nnn* – and for *bbb*, separate forward and reciprocal flows. Panel D shows robustness to alternative buyback definitions (e.g., requiring multiple reciprocal quarters or a minimum return-share threshold).

Panel A. Prevalence and coverage

Share active dyads with buyback	0.0424
Value share in buyback dyads (value)	0.4685
Value share in buyback dyads (counts)	0.2482
Share of firms with $\geq$1 buyback tie	0.4549
Share of firms as buyback supplier	0.3641
Share of firms as buyback customer	0.3413
Share of firms in both roles	0.2506
Median # buyback customers (suppliers)	2.0000
Median # buyback suppliers (customers)	2.0000
Median sales exposure to BB partners (value)	0.3051
Median purchase exposure from BB partners (value)	0.3214
Median sales exposure to BB partners (counts)	0.2339
Median purchase exposure from BB partners (counts)	0.1629

Panel B. Network roles and flow composition by buyback status

Share of suppliers with ≥1 buyback tie	0.4982
Share of customers with ≥1 buyback tie	0.4917
bbb (reciprocal) share [value]	0.0701
bbb (forward) share [value]	0.3983
bbn (forward) share [value]	0.4051
bnn (forward) share [value]	0.0592
nbn (forward) share [value]	0.0569
nnn (forward) share [value]	0.0103
bbb (reciprocal) share [counts]	0.0700
bbb (forward) share [counts]	0.1782
bbn (forward) share [counts]	0.5327
bnn (forward) share [counts]	0.0968
nbn (forward) share [counts]	0.1039
nnn (forward) share [counts]	0.0183

Panel C. Intensity and persistence

p10 (return-share value)	0.0068
p25	0.0318
p50	0.1154
p75	0.2613
p90	0.3889
p10 (return-share counts)	0.0702
p25	0.1589
p50	0.3333
p75	0.5000
p90	0.6087
Mean reciprocal quarters	5.5963
Median reciprocal quarters	4.0000
Median dyad share of forward sales (value)	0.1001
Median dyad share of forward sales (counts)	0.1341

Panel D. Robustness to alternative buyback definitions

Dyad share [≥1 reciprocal quarter]	0.0424
Value share [≥1 reciprocal quarter]	0.4685
Dyad share [≥2 reciprocal quarters]	0.0421
Value share [≥2 reciprocal quarters]	0.4684
Dyad share [return share amounts ≥ 0.10]	0.0227
Value share [return share amounts ≥ 0.10]	0.2178

Table 2: Buyback prevalence by sector

The table reports dyad-level aggregates from pre-COVID VAT invoices (2017Q1-2019Q4). Panel A groups dyads by the supplier's sector (Korean Standard Industrial Classification first letter, A-J), and Panel B by the customer's sector. Columns 1-2 report the number of active supplier-customer dyads and their share of all dyads. Columns 3-4 report the number of buyback dyads and their share of the sector's active dyads. Columns 5-6 report forward (supplier-to-customer) sales in KRW billions and the sector's share of total forward sales. Columns 7-8 report forward sales via buyback dyads (Figure 1) in KRW billions and their share of the sector's forward sales.

Panel A. By supplier sector

	(1) # Dyads	(2) % Dyads	(3) # Buyback dyads	(4) % Buyback dyads	(5) Sales	(6) % Sales	(7) Buyback sales	(8) % Buyback sales
Agriculture, Forestry & Fishing	12,801	.000	954	.074	4,341	.001	1,880	.433
Mining & Quarrying	13,564	.000	759	.055	3,568	.001	1,452	.406
Manufacturing	5,031,006	.366	244,508	.048	1,917,320	.551	1,022,137	.533
Electricity, Gas, Steam & Air	110,775	.008	3,514	.031	30,962	.008	8,210	.265
Water, Sewerage & Waste	154,692	.011	6,271	.040	29,175	.008	10,237	.350
Construction	940,468	.068	32,302	.034	334,383	.096	96,118	.287
Wholesale & Retail Trade	3,903,004	.284	199,554	.051	722,333	.207	301,907	.417
Transportation & Storage	684,932	.049	23,592	.034	129,030	.037	56,025	.434
Accommodation & Food Service	88,746	.006	1,288	.014	5,159	.001	2,111	.409
Information & Communication	1,125,439	.082	37,036	.032	141,581	.040	69,426	.490
Financial & Insurance	202,938	.014	1,290	.006	13,546	.003	4,840	.357
Real Estate	51,004	.003	1,122	.021	7,464	.002	1,388	.185
Professional, Scientific & Technical	793,784	.057	16,921	.021	65,047	.018	21,790	.334
Administrative & Support Services	364,959	.026	8,658	.023	59,221	.017	25,023	.422
Public Administration & Defense	22,310	.001	274	.012	480	.000	50	.104
Education	29,267	.002	720	.024	1,615	.000	602	.372
Human Health & Social Work	8,962	.000	213	.023	476	.000	106	.221
Arts, Entertainment & Recreation	22,118	.001	1,176	.053	4,251	.001	2,846	.669
Other Services	164,035	.011	2,160	.013	4,854	.001	1,718	.353

Panel B. By customer sector

	(1) # Dyads	(2) % Dyads	(3) # Buyback dyads	(4) % Buyback dyads	(5) Sales	(6) % Sales	(7) Buyback sales	(8) % Buyback sales
Agriculture, Forestry & Fishing	45,046	.003	885	.019	4,542	.001	1,421	.312
Mining & Quarrying	13,399	.000	587	.043	1,880	000	689	.366
Manufacturing	5,666,448	.412	230,413	.040	1,719,644	.494	887,330	.515
Electricity, Gas, Steam & Air	41,935	.003	5,708	.136	37,100	.010	22,288	.600
Water, Sewerage & Waste	135,549	.009	6,240	.046	20,527	.005	7,472	.364
Construction	2,204,802	.160	31,470	.014	352,701	.101	83,969	.238
Wholesale & Retail Trade	3,033,660	.221	203,986	.067	831,969	.239	411,145	.494
Transportation & Storage	340,430	.024	23,151	.068	100,056	.028	54,608	.545
Accommodation & Food Service	66,761	.004	2,131	.031	16,173	.004	5,878	.363
Information & Communication	661,431	.048	37,939	.057	141,759	.040	79,997	.564
Financial & Insurance	79,346	.005	3,703	.046	48,898	.014	16,731	.342
Real Estate	74,596	.005	1,273	.017	26,953	.007	4,499	.166
Professional, Scientific & Technical	541,163	.039	19,249	.035	61,892	.017	25,156	.406
Administrative & Support Services	252,074	.018	8,381	.033	27,726	.007	11,002	.396
Public Administration & Defense	193,541	.014	855	.004	36,379	.010	661	.018
Education	153,977	.011	905	.005	10,422	.002	1,370	.131
Human Health & Social Work	67,118	.004	476	.007	13,025	.003	823	.063
Arts, Entertainment & Recreation	45,483	0.003	1,240	.027	6,768	.001	3,340	.493
Other Services	108,043	.007	3,721	.034	16,382	.004	9,478	.578

Table 3: Pre-COVID summary statistics for supplier-customer dyads.
The table reports mean, standard deviation, and selected percentiles for each listed variable. Dyad outcomes are aggregated to the 2019 annual total; dyad characteristics are computed over the pre-COVID window (2017Q1-2019Q4); and firm characteristics are measured in 2009. The observation count N (bottom row) is smaller for reciprocal-flow outcomes, which are defined only for buyback dyads (Figure 1). See Table A1 for variable definitions.

	Mean	S.D.	10^{th}	25^{th}	50^{th}	75^{th}	90^{th}
Dyad outcomes							
Log Forward Sales	2.25	2.46	-0.99	0.49	2.27	4.01	5.48
Log Forward Invoices	1.65	1.13	0.00	0.69	1.79	2.48	3.00
Log Reciprocal Sales	2.32	2.33	-0.67	0.72	2.31	3.90	5.38
Log Reciprocal Invoices	1.60	1.15	0.00	0.69	1.61	2.48	3.09
Dyad characteristics							
Log Transacting Qtr	1.62	0.73	0.69	1.10	1.79	2.30	2.48
Log Consec. Transacting Qtr	1.29	0.90	0.00	0.69	1.39	2.08	2.48
Log Distance	3.34	1.70	0.00	2.52	3.40	4.66	5.58
Customer characteristics							
Log Assets	15.64	2.17	13.43	14.23	15.22	16.37	18.58
Log Firm Age	2.30	0.90	1.10	1.79	2.48	2.94	3.33
Debt to Assets	0.55	0.26	0.20	0.36	0.56	0.72	0.84
Return on Assets	0.06	0.12	-0.02	0.02	0.05	0.10	0.18
Asset Turnover	1.77	1.52	0.50	0.80	1.31	2.21	3.54
Log CEO Age	3.99	0.17	3.76	3.89	4.01	4.11	4.19
Supplier characteristics							
Log Assets	16.12	2.94	13.35	14.24	15.37	16.99	20.49
Log Firm Age	2.43	0.91	1.10	1.95	2.64	3.04	3.43
Debt to Assets	0.52	0.24	0.19	0.35	0.53	0.69	0.82
Return on Assets	0.08	0.12	0.00	0.03	0.06	0.12	0.20
Asset Turnover	1.70	1.50	0.51	0.74	1.24	2.11	3.38
Log CEO Age	4.01	0.16	3.78	3.91	4.03	4.11	4.19
N = 11,383,541 in all rows but the 3rd and 4th, where N = 606,639.							

Table 4: Buyback agreements and pre-COVID order volume.

The table reports dyad-level ordinary least squares estimates from regressions of outcomes on *Buyback*, an indicator equal to one for buyback dyads (Figure 1). Outcomes are measured in 2019: *Log Forward Invoices* in Columns 1-3 and *Forward Sales per Invoice* in Columns 4-6. Forward invoices are the number of supplier-to-customer sales invoices, and forward sales per invoices are VAT-exclusive forward sales divided by the number of forward invoices. Table A1 defines all variables. Standard errors in parentheses are heteroskedasticity-robust in Columns 1 and 4, two-way clustered by customer and supplier industry in Columns 2 and 5, and clustered by customer-supplier industry pair in Columns 3 and 6. Industries follow Korean Standard Industrial Classification 2-digit codes. *, **, and *** denote significance at the 10%, 5%, and 1% levels, respectively.

	(1)	(2)	(3)	(4)	(5)	(6)
	Log Forward Invoices			Log Forward Sales per Invoice		
Buyback	0.3437***	0.3266***	0.3018***	1.6351***	1.4165***	1.0215***
	(0.001)	(0.011)	(0.004)	(0.002)	(0.042)	(0.022)
Customer Industry FE		✓			✓	
Supplier Industry FE		✓			✓	
Industry Pair FE			✓			✓
Customer FE			✓			✓
Supplier FE			✓			✓
Adj. R^2	0.0200	0.1019	0.3009	0.0240	0.2469	0.5946
N	13,724,842	13,724,622	13,626,985	13,724,842	13,724,622	13,626,985

Table 5: Entropy-balancing diagnostics

The table compares buyback (treated) and non-buyback (control) dyads before and after entropy balancing when the outcome is *Log Forward Sales* (Figure 4). Controls are reweighted to match treated means on pre-COVID (2017Q1-2019Q4) covariates – dyad attributes, customer and supplier firm characteristics (measured in 2019), and customer and supplier industry indicators – plus year-to-year changes in the outcome. For each covariate, we report, before weighting (Columns 1-4), the treated mean $\bar{X}_T$, control mean $\bar{X}_C$, difference $\bar{X}_T - \bar{X}_C$, and the variance ratio $\text{Var}(X_T)/\text{Var}(X_C)$; and after weighting (Columns 5-6), the treated-reweighted control difference $\bar{X}_T - \bar{X}_C^w$ and $\text{Var}(X_T)/\text{Var}(X_C^w)$. ESS denotes the effective sample size implied by the weights. See Table A1 for variable definitions.

	(1)	(2)	(3)	(4)	(5)	(6)
			Pre-Balancing (ESS = 1,584,835)		Post-Balancing (ESS = 763,958)	
	$\bar{X}_T$	$\bar{X}_C$	$\bar{X}_T - \bar{X}_C$	$\frac{\text{Var}(X_T)}{\text{Var}(X_C)}$	$\bar{X}_T - \bar{X}_C^w$	$\frac{\text{Var}(X_T)}{\text{Var}(X_C^w)}$
Dyad characteristics						
Log Transacting Qtr.	2.28	2.11	0.17	2.01	0.00	0.94
Log Consecutive Transacting Qtr.	2.05	1.74	0.32	1.78	0.00	0.96
Log Distance	2.99	3.40	-0.41	0.87	0.00	0.95
Customer characteristics						
Log Assets	16.34	15.80	0.54	0.69	0.00	0.94
Log Firm Age	2.46	2.42	0.04	0.96	0.00	1.01
Debt to Assets	0.56	0.54	0.02	1.15	0.00	1.08
Return on Assets	0.06	0.06	0.00	1.01	0.00	0.99
Asset Turnover	1.89	1.67	0.21	0.78	0.00	1.11
Log CEO Age	3.99	4.00	-0.01	1.06	0.00	1.07
Supplier characteristics						
Log Assets	15.81	16.58	-0.78	1.96	0.00	1.12
Log Firm Age	2.36	2.56	-0.20	0.95	0.00	1.05
Debt to Assets	0.56	0.52	0.05	1.04	0.00	1.11
Return on Assets	0.07	0.08	-0.01	1.23	0.00	1.20
Asset Turnover	1.87	1.58	0.29	0.78	0.00	1.10
Log CEO Age	3.99	4.02	-0.03	0.91	0.00	1.02
Outcome variable changes						
$\Delta_{[2018,2019]}$ Log Forward Sales	-0.08	-0.13	0.05	0.84	0.00	0.71
$\Delta_{[2017,2018]}$ Log Forward Sales	0.13	0.09	0.04	0.76	0.00	0.70

Table 6: COVID-19, buybacks, and sales reallocation.

The table reports difference-in-differences estimates of the COVID-19 shock on dyad-year outcomes using an entropy-balanced sample that reweights control dyads to the pre-COVID covariate means of buyback dyads (balancing set in Table 5). *Post* equals one for 2020Q1-2021Q and *Buyback* equals one for buyback dyads. *Log Reciprocal Sales* (Panel A, Columns 1-4; Panel B, Column 1) is the log of one plus VAT-exclusive customer-to-supplier sales for buyback links; for non-buyback links with no reverse flows, the outcome is set to *Log Forward Sales*. *Log Forward Sales* (Panel A, Columns 5-8; Panel B, Column 2) is the log of one plus VAT-exclusive supplier-to-customer sales for all link types. Buyback dyads and link types are defined in Figure 1. Panel A, Columns 3-4 and 7-8, and Panel B include firm-level controls from Table 5. Standard errors are two-way clustered by supplier and customer. *, **, and *** denote significance at the 10%, 5%, and 1% levels, respectively.

Panel A. Sales via buyback links of buyback-active firms

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Log Reciprocal Sales				Log Forward Sales			
Post × Buyback	0.104***	0.104***	0.0739***	0.0698***	-0.0371***	-0.0365***	-0.0985***	-0.115***
	(0.00942)	(0.00988)	(0.0116)	(0.0139)	(0.00447)	(0.00454)	(0.00555)	(0.00857)
Controls			✓	✓			✓	✓
Dyad FE	✓	✓	✓	✓	✓	✓	✓	✓
Customer × Year FE	✓	✓			✓	✓		
Supplier × Year FE	✓	✓			✓	✓		
Cus. Ind. × Year FE			✓	✓			✓	✓
Sup. Ind. × Year FE			✓	✓			✓	✓
Adj. R^2	0.906	0.907	0.813	0.808	0.880	0.878	0.806	0.791
N	6,162,543	5,231,751	1,335,082	575,272	6,609,857	5,695,613	1,772,769	1,014,477
Buyback =								
bbb	1	1	1	1	1	1	1	1
bbn	0	0			0	0		
bnn	0	0			0	0		
nbn	0		0		0		0	
nnn	0		0	0	0		0	0

Panel B. Sales via all links of buyback-active firms

	(1) Log Reciprocal Sales	(2) Log Forward Sales
Post × Buyback	0.0334***	-0.0655***
	(0.00904)	(0.00451)
Controls	✓	✓
Dyad FE	✓	✓
Cus. Ind. × Year FE	✓	✓
Sup. Ind. × Year FE	✓	✓
Adj. R^2	0.844	0.835
N	6,463,083	6,907,394
Buyback =		
bbb	1	1
bbn	1	1
bnn	1	1
nbn	0	0
nnn	0	0

Table 7: Proximity to final demand and heterogeneous COVID-19 effects.
The table reports difference-in-differences estimates of the COVID-19 shock on dyad-year outcomes using an entropy-balanced sample that reweights control dyads to the pre-COVID covariate means of buyback dyads (balancing set in Table 5). *Post*, *Buyback*, are *Log Reciprocal Sales* are defined in Table 6. *High B2C* equals one for firms whose pre-COVID (2017-2019) share of business-to-customer (B2C) sales is above the sample median. Buyback status and link types follow Figure 1. Column 1 augments the baseline specification in Equation 1 with an interaction for *High B2C*. Columns 2-5 restrict the sample to retail (Korean Standard Industrial Classification (KSIC) G45 and G47), wholesale (KSIC G46), manufacturing (KSIC C), and all other sectors, respectively. Standard errors are two-way clustered by supplier and customer. *, **, and *** denote significance at the 10%, 5%, and 1% levels, respectively.

	(1)	(2)	(3)	(4)	(5)
	Log Reciprocal Sales				
Sample	Full-Sample	Retail	Wholesale	Manufacturing	Others
Post × Buyback	0.0954***	0.259***	0.187***	0.100***	0.0368*
	(0.00960)	(0.0810)	(0.0186)	(0.0121)	(0.0205)
Post × Buyback × High B2C	0.0587***				
	(0.0202)				
Dyad FE	✓	✓	✓	✓	✓
Customer × Year FE	✓	✓	✓	✓	✓
Supplier × Year FE	✓	✓	✓	✓	✓
Adj. R^2	0.906	0.822	0.857	0.905	0.935
N	6,162,543	76,984	1,154,517	2,345,295	2,130,747
Buyback =					
bbb	1	1	1	1	1
bbn	0	0	0	0	0
bnn	0	0	0	0	0
nbn	0	0	0	0	0
nnn	0	0	0	0	0

Table 8: Determinants of buyback formation.
Panel A reports dyad-level linear probability models (LPMs) for $\mathbb{1}(Buyback)$, equal to one if the dyad is a buyback pair. Regressors measured pre-COVID capture geographic proximity (log distance) and relationship depth (log quarters transacted; log consecutive quarters transacted). Panel B reports firm-level LPMs for $\mathbb{1}(Buyback\ Supplier)$ (Columns 1-2) and $\mathbb{1}(Buyback\ Customer)$ (Columns 3-4), which equal one for firms that serve exclusively as buyback suppliers or exclusively as buyback customers in their networks. Buyback status and role assignment follow Figure 1. Covariates include sales-growth volatility (standard deviation of quarterly sales growth over 2017-2019) and, measured in 2019, fundamentals (log assets, log age, debt/assets, return on assets, asset turnover, log CEO age), innovation (R&D/sales, log patents), network scope (log number of partners; partner Herfindahl-Hirschman Index (HHI)), and partner-industry concentration (Korean Standard Industrial Classification (KSIC) 2-digit HHI; sales-weighted average within-2-digit 3-digit HHI). All covariates are standardized (demeaned and divided by their sample standard deviations). Table A1 defines all variables. Standard errors in parentheses are heteroskedasticity-robust (Panel A, Column 1; Panel B, Columns 1 and 3), clustered by customer and supplier industries (Panel A, Column 2; Panel B, Columns 2 and 4), or clustered by customer-supplier industry pair (Panel A, Column 3). *, **, and *** denote significance at the 10%, 5%, and 1% levels, respectively.

Panel A. Dyad-level

	(1)	(2)	(3)
		𝟙(Buyback)	
Log Distance	-0.0116***	-0.0101***	-0.0106***
	(0.000)	(0.002)	(0.001)
Log Transacting Qtr.	0.0234***	0.0249***	0.0350***
	(0.000)	(0.003)	(0.003)
Log Consecutive Transacting Qtr.	0.0153***	0.0144***	0.0088***
	(0.000)	(0.003)	(0.001)
Customer Industry FE		✓	
Supplier Industry FE		✓	
Industry Pair FE			✓
Customer FE			✓
Supplier FE			✓
Adj. R^2	0.0304	0.0479	0.1804
N	8,033,348	8,033,346	7,903,736

Panel B. Firm-level

	(1)	(2)	(3)	(4)
	𝟙(Buyback Customer)		𝟙(Buyback Supplier)	
Sales Growth Volatility	0.0163***	0.0160***	-0.0041***	-0.0026*
	(0.001)	(0.002)	(0.001)	(0.001)
Log Assets	0.0605***	0.0622***	0.0280***	0.0346***
	(0.001)	(0.005)	(0.001)	(0.005)
Log Firm Age	-0.0069***	-0.0097***	-0.0172***	-0.0158***
	(0.001)	(0.001)	(0.001)	(0.003)
Debt to Assets	0.0083***	0.0080***	0.0110***	0.0095***
	(0.001)	(0.001)	(0.001)	(0.001)
Return on Assets	-0.0118***	-0.0085***	-0.0063***	-0.0079***
	(0.001)	(0.003)	(0.001)	(0.002)
Asset Turnover	0.0284***	0.0218***	-0.0066***	0.0047
	(0.001)	(0.004)	(0.001)	(0.004)
Log CEO Age	-0.0143***	-0.0140***	-0.0045***	-0.0061***
	(0.001)	(0.002)	(0.001)	(0.002)
R&D to Sales	0.0023*	0.0031**	0.0129***	0.0094***
	(0.001)	(0.002)	(0.001)	(0.002)
Log Patent Counts	0.0194***	0.0200***	0.0145***	0.0037
	(0.001)	(0.002)	(0.001)	(0.004)
Log Unique Partners per Firm	0.0249***	0.0235***	0.0505***	0.0536***
	(0.002)	(0.006)	(0.002)	(0.004)
Partner HHI	-0.0268***	-0.0228***	-0.0233***	-0.0191***
	(0.002)	(0.004)	(0.002)	(0.003)
Partner (2-digit) Ind. HHI	-0.0030*	-0.0080*	0.0134***	0.0047
	(0.002)	(0.004)	(0.002)	(0.004)
Partner (within 2-digit, 3-digit) Ind. HHI	0.0027**	0.0031	0.0127***	0.0111***
	(0.001)	(0.003)	(0.001)	(0.003)
Industry FE		✓		✓
Adj. R^2	0.0320	0.0406	0.0188	0.0350
N	167,782	167,781	167,782	167,781

Table 9: Determinants of honoring buyback agreements.
Panel A reports dyad-level linear probability model (LPM) estimates for $\mathbb{1}$(*Buyback Honored*), which equals one if a buyback dyad's reciprocal (customer-to-supplier) sales in 2020-2021 exceed its pre-COVID baseline (2017Q1-2019Q4). Buyback dyads are defined in Figure 1. Panel B estimates supplier-level LPM estimates for $\mathbb{1}$(*Buyback Supplier Honors*), which equals one if a buyback supplier honors at least one agreement during COVID (i.e., receives reciprocal sales above its pre-COVID level). Covariates follow Table 8. All covariates are standardized (demeaned and divided by their sample standard deviations). See Table A1 for variable definitions. Standard errors in parentheses are heteroskedasticity-robust (Panel A, Column 1; Panel B, Column 1), clustered by 2-digit supplier industry (Panel B, Column 2), clustered by 2-digit customer and supplier industries (Panel A, Column 2), or clustered by customer-supplier industry pair (Panel A, Column 3). Industries are coded using the Korean Standard Industrial Classification. *, **, and *** denote significance at the 10%, 5%, and 1% levels, respectively.

Panel A. Dyad-level

	(1)	(2)	(3)
	$\mathbb{1}$(Buyback Honored)		
Log Distance	-0.0119***	-0.0167***	-0.0238***
	(0.001)	(0.002)	(0.003)
Log Transacting Qtr.	0.0030	0.0085	0.0782***
	(0.002)	(0.009)	(0.007)
Log Consecutive Transacting Qtr.	0.1593***	0.1470***	0.0891***
	(0.002)	(0.008)	(0.005)
Customer Industry FE		✓	
Supplier Industry FE		✓	
Industry Pair FE			✓
Customer FE			✓
Supplier FE			✓
Adj. R^2	0.1063	0.1213	0.2547
N	457,582	457,582	285,003

Panel B. Firm-level

	(1)	(2)
	𝟙(Buyback Supplier Honors)	
Sales Growth Volatility	-0.0153***	-0.0122***
	(0.002)	(0.003)
Log Assets	0.0441***	0.0436***
	(0.003)	(0.004)
Log Firm Age	-0.0299***	-0.0292***
	(0.003)	(0.003)
Debt to Assets	0.0097***	0.0011
	(0.002)	(0.002)
Return on Assets	0.0108***	0.0069**
	(0.002)	(0.003)
Asset Turnover	0.0165***	0.0205***
	(0.003)	(0.004)
Log CEO Age	0.0040*	0.0006
	(0.002)	(0.002)
R&D to Sales	-0.0055***	-0.0057***
	(0.002)	(0.002)
Log Patent Counts	0.0009	-0.0011
	(0.002)	(0.003)
Log Unique Partners per firm	0.0472***	0.0450***
	(0.003)	(0.006)
Partner HHI	0.0175***	0.0147***
	(0.004)	(0.005)
Partner (2-digit) Ind. HHI	0.0145***	0.0119**
	(0.003)	(0.005)
Partner (within 2-digit, 3-digit) Ind. HHI	0.0017	0.0002
	(0.002)	(0.005)
Industry FE		✓
Adj. R^2	0.0176	0.0285
N	47,093	47,090

Table A1: Variable definitions.
The table defines all variables used in the paper. VAT records provide quarterly invoice counts and VAT-exclusive supply values for each supplier-customer dyad (covering goods and most services). Buyback status and role assignment follow Figure 1. The pre-COVID period is 2017Q1-2019Q4, and the COVID period is 2020Q1-2021Q4. Unless otherwise noted, industries follow Korean Standard Industrial Classification (KSIC) 2-digit codes.

Variable	Definition
Dyad outcomes	
Log Forward Sales	Log of one plus VAT-exclusive supply value of invoices from supplier to customer.
Log Reciprocal Sales	Log of one plus VAT-exclusive supply value of invoices from customer to supplier for buyback dyads and from supplier to customer for non-buyback dyads.
Log Forward Invoices	Log of one plus number of invoices from supplier to customer.
Log Reciprocal Invoices	Log of one plus number of invoices from customer to supplier.
Log Forward Sales per Invoice	Log of one plus forward sales divided by forward invoices.
$\mathbb{1}$(Buyback)	One for buyback dyads that had bilateral transaction in the pre-COVID period and zero for non-buyback dyads.
$\mathbb{1}$(Buyback Supplier)	One for a firm involved in a buyback agreement exclusively as a supplier and zero otherwise.
$\mathbb{1}$(Buyback Customer)	One for a firm involved in a buyback agreement exclusively as a customer and zero otherwise.
$\mathbb{1}$(Buyback Honored)	One if a buyback dyad's average COVID-period reciprocal sales exceed its pre-COVID average and zero otherwise.
$\mathbb{1}$(Buyback Supplier Honors)	One for a supplier firm that fulfilled at least one buyback agreement post-COVID by receiving returns above pre-COVID levels in at least one of its buyback links.
Dyad characteristics	
Log Transacting Qtr.	Log of one plus number of quarters with positive trade over the pre-COVID period.
Log Consec. Transacting Qtr.	Log of one plus longest uninterrupted run of quarters with positive trade over the pre-COVID period.
Log Distance	Log of one distance in kilometers between the locations of supplier and customer.

Firm characteristics	
Sales Growth Volatility	Within-firm standard deviation of quarterly sales growth over the pre-COVID period.
Log Assets	Log of one plus total assets.
Log Firm Age	Log of one plus years since founding.
Debt to Assets	Total liabilities divided by total assets.
Return on Assets	Earnings before interest and taxes divided by total assets.
Asset Turnover	Sales divided by total assets.
Log CEO Age	Log of one plus CEO age.
R&D to Sales	Total R&D expenditure divided by sales.
Log Patent Counts	Log of one plus the number of patents.
Log Unique Partners per Firm	Log of one plus number of unique trading partners
Partner HHI	Herfindahl-Hirschman Index (HHI) of partner concentration: $\text{HHI}_i^{\text{partner}} = \sum_{j \in P_i} s_{ij}^2$, where P_i is the set of firm i's partners, T_{ij} is the VAT-exclusive trade value (sales to j if i is supplier or purchases from j if i is customer) aggregated over the pre-COVID period, $T_{i\cdot} = \sum_{j \in P_i} T_{ij}$, and $s_{ij} = T_{ij}/T_{i\cdot}$.
Partner (2-digit) Ind. HHI	HHI of partner industry concentration at the 2-digit KSIC level: $\text{HHI}_i^{\text{2d}} = \sum_{g \in \mathcal{G}_{2d}} s_{ig}^2$, where $T_{ig} = \sum_{j:\,\text{KSIC}_{2d}(j)=g} T_{ij}$ is the VAT-exclusive trade value with partners in 2-digit industry g, $T_{i\cdot} = \sum_g T_{ig}$, and $s_{ig} = T_{ig}/T_{i\cdot}$.
Partner (within 2-digit, 3-digit) Ind. HHI	Weighted average HHI of within-2-digit 3-digit industry concentration: $\text{HHI}_i^{\text{3d}\mid\text{2d}} = \sum_{g \in \mathcal{G}_{2d}} \omega_{ig} \Big(\sum_{h \in \mathcal{H}_{3d}(g)} s_{igh}^2 \Big)$, where $T_{igh} = \sum_{j:\,\text{KSIC}_{3d}(j)=h} T_{ij}$, $T_{ig} = \sum_h T_{igh}$, $s_{igh} = T_{igh}/T_{ig}$, and the weight $\omega_{ig} = T_{ig} / \sum_{g'} T_{ig'}$.

Risk Management with Inventory Buybacks

Sunwoo Hwang and Sung Kwan Lee

ONLINE APPENDIX

OA Theory of Buybacks as Relational Insurance

This section embeds inventory buybacks in a repeated supplier–customer relationship in which the refund promise is *informal* (non-verifiable and hence not enforceable). Key return contingencies—eligibility, condition, timing, and verification that inventory is genuinely unsold—are costly to specify ex ante and verify ex post, so performance must be sustained by the value of future trade rather than by legal enforcement. Formally, the buyback clause is an *incomplete contract* (Williamson, 1975, 1979, 1985; Hart, 1995; Tirole, 1999; MacLeod and Malcomson, 1989). The model links downstream insurance demand, forward trade scale, and state-contingent reverse flows of returns. It also delivers feasibility conditions for informal buybacks, tying them to relationship continuation value (relational capital) (Telser, 1980; Klein and Leffler, 1981; Bull, 1987; Baker et al., 2002; Levin, 2003). Relative to the supply-chain literature on buybacks (Pasternack, 1985; Cachon, 2003; Kandel, 1996), the key departure is that the return clause is not contractible and must therefore be relational.

OA.1 Environment and contracts

A supplier S and a customer firm C interact over $t = 0, 1, 2, \ldots$ with common discount factor $\delta \in (0, 1)$. In each period, C orders $q \geq 0$ before demand is realized. A random sell-through rate $d \in [0, 1]$ determines sales dq and unsold inventory $(1 - d)q$. The variable d is i.i.d. over time with $\mathbb{E}[d] = \mu$ and $\mathrm{Var}(d) = \sigma^2$. The retail price is normalized to $P = 1$. The supplier produces at constant unit cost c. The stage-game contracting choice is between *spot* terms with wholesale price w and a *buyback* arrangement under which the customer pays w_b per unit up front and may return unsold units for a per-unit refund $b \in (0, 1)$ at the end of the period. We assume $w > c$ and $w_b > b$ to rule out pure return arbitrage. If the supplier accepts returned saleable units, it can *redeploy* them to alternative outlets and recover value $v \in [0, 1)$ per unit.[23] We assume $v < b$ to focus on the empirically relevant case; if $v \geq b$, honoring is weakly privately optimal and the self-enforcement constraint is slack.

[23] Higher v corresponds to more standardized goods and stronger outside options; lower v corresponds to relationship-specific inventory (Klein et al., 1978; Williamson, 1985; Grossman and Hart, 1986; Hart and Moore, 1990).

OA.2 Stage payoffs and CEO preferences

Under spot terms, customer and supplier profits in a period with realization d are

$$\pi_C^0(q,d) = qd - wq = q(d-w), \qquad \pi_S^0(q) = wq - cq = (w-c)q. \tag{2}$$

Under buyback agreements with wholesale price w_b and refund price b, the customer and supplier profits are

$$\pi_C^B(q,d) = qd - w_b q + b(1-d)q = q\big((1-b)d + b - w_b\big), \tag{3}$$

$$\pi_S^B(q,d) = w_b q - cq - b(1-d)q + v(1-d)q = q\big(w_b - c - (b-v)(1-d)\big).$$

The supplier is risk-neutral. The customer is run by a risk-averse CEO whose compensation loads on firm profit. Let $\alpha \in (0,1]$ be the fraction of firm profit internalized by the CEO (e.g., incentive pay), and let $\gamma > 0$ denote absolute risk aversion. We use a mean–variance certainty-equivalent objective:

$$U_C^k(q) = \alpha\,\mathbb{E}\big[\pi_C^k(q,d)\big] - \frac{\gamma}{2}\alpha^2\,\mathrm{Var}\big(\pi_C^k(q,d)\big), \qquad k \in \{0, B\}. \tag{4}$$

OA.3 Ordering under spot and buybacks

Under spot trade, $\mathbb{E}[\pi_C^0(q,d)] = q(\mu - w)$ and $\mathrm{Var}(\pi_C^0(q,d)) = q^2\sigma^2$. Maximizing (4) yields

$$q^0 = \frac{\mu - w}{\gamma\alpha\,\sigma^2}, \tag{5}$$

assuming $\mu > w$, with $\frac{\partial q^0}{\partial \mu} > 0$, $\frac{\partial q^0}{\partial w} < 0$, $\frac{\partial q^0}{\partial \gamma} < 0$, $\frac{\partial q^0}{\partial \alpha} < 0$, and $\frac{\partial q^0}{\partial \sigma^2} < 0$.

Under buybacks, (3) implies $\mathbb{E}[\pi_C^B(q,d)] = q\big((1-b)\mu + b - w_b\big)$ and $\mathrm{Var}(\pi_C^B(q,d)) = q^2(1-b)^2\sigma^2$, so the CEO's optimal order is

$$q^B = \frac{(1-b)\mu + b - w_b}{\gamma\alpha\,(1-b)^2\sigma^2}, \tag{6}$$

whenever the numerator is positive. Note that v does not directly affect q^B because it accrues to the supplier upon redeployment, not to the customer.

Actuarially fair buyback premium. To isolate insurance from expected transfers on the *customer side*, we adopt the standard benchmark in which the buyback wholesale premium prices the supplier's *expected refund payments* (Pasternack, 1985; Kandel, 1996):

$$w_b \equiv w + b(1-\mu). \tag{7}$$

Under (7), expected customer profit at any fixed q is unchanged while variance is reduced:

$$\mathbb{E}\big[\pi_C^B(q,d)\big] = q(\mu - w) = \mathbb{E}\big[\pi_C^0(q,d)\big]\,, \tag{8}$$

$$\mathrm{Var}\big(\pi_C^B(q,d)\big) = (1-b)^2\,\mathrm{Var}\big(\pi_C^0(q,d)\big)\,. \tag{9}$$

Hence, substituting 7 into 6 yields the following optimal order:

$$q^B(b) = \frac{\mu - w}{\gamma\alpha\,(1-b)^2\sigma^2} = \frac{q^0}{(1-b)^2} > q^0, \qquad b \in (0,1), \tag{10}$$

with $\frac{\partial q^B}{\partial b} = \frac{2q^0}{(1-b)^3} > 0$ and , $\frac{\partial q^B}{\partial \gamma} < 0$, $\frac{\partial q^B}{\partial \alpha} < 0$, $\frac{\partial q^B}{\partial \sigma^2} < 0$. At a fixed scale q, the variance reduction from introducing b is

$$\mathrm{Var}\big(\pi_C^0(q,d)\big) - \mathrm{Var}\big(\pi_C^B(q,d)\big) = q^2\sigma^2(2b - b^2), \tag{11}$$

so $\partial(\mathrm{Var}(\pi_C^0) - \mathrm{Var}(\pi_C^B))/\partial b > 0$ and $\partial(\mathrm{Var}(\pi_C^0) - \mathrm{Var}(\pi_C^B))/\partial \sigma^2 > 0$.

OA.4 Repeated interaction and self-enforcement

Because refunds are informal, buybacks must be self-enforcing. Consider a grim-trigger strategy. The supplier honors refunds unless it has reneged in the past. After any deviation, the relationship reverts to spot trade forever. Let V_S^C and V_S^N denote the supplier's continuation values on the cooperative and punishment paths. If the supplier reneges in state d, it avoids paying b on returned units but also forgoes redeployability value v on those units. Thus, the one-shot deviation gain is

$$G(d) = (b - v)(1 - d)q^B. \tag{12}$$

Self-enforcement requires $G(d) \leq \delta\big(V_S^C - V_S^N\big)$ for all $d \in [0,1]$. The tightest constraint is at $d = 0$, yielding the worst-case IC:

$$(b - v)\, q^B \leq \delta\big(V_S^C - V_S^N\big). \tag{13}$$

Note that if $v \geq b$, then $G(d) \leq 0$ and the refund is trivially credible.

Under the customer-side fair pricing rule (7), expected supplier profit under buybacks is

$$\mathbb{E}\big[\pi_S^B(q^B, d)\big] = q^B\Big(w_b - c - (b - v)(1 - \mu)\Big) = q^B\Big((w - c) + v(1 - \mu)\Big), \tag{14}$$

while under spot terms $\mathbb{E}[\pi_S^0(q^0)] = (w - c)q^0$. Therefore,

$$V_S^C - V_S^N = \frac{1}{1 - \delta}\left(\Big((w - c) + v(1 - \mu)\Big)q^B - (w - c)q^0\right). \tag{15}$$

Substituting (15) into (13) and using (10) yields a closed-form minimal patience condition:

$$\delta \;\geq\; \delta^*(b, v) \;\equiv\; \frac{b - v}{(b - v) \;+\; (w - c)\,(2b - b^2) \;+\; v(1 - \mu)}. \tag{16}$$

Comparative statics are immediate: $\frac{\partial \delta^*}{\partial b} > 0$, $\frac{\partial \delta^*}{\partial (w-c)} < 0$, $\frac{\partial \delta^*}{\partial v} < 0$, $\frac{\partial \delta^*}{\partial \mu} > 0$. Thus, greater redeployability (higher v) lowers the patience required to sustain informal refunds: it reduces the temptation to renege in bad states (12) and raises the continuation value from cooperation (14). Equivalently, for any (δ, v), the maximal enforceable refund $b^*(\delta, v)$ is increasing in both δ and v (and in $(w - c)$; Figure OB2), and can be characterized as the unique $b \in (0, 1)$ solving $\delta = \delta^*(b, v)$.[24] The customer's incentive to adopt buybacks is automatic under (7) because buybacks weakly raise the certainty equivalent at any fixed q via (11), and strictly raise it at the optimum because $q^B > q^0$.

OA.5 Testable implications

The model yields four implications guiding our empirical analysis.

[24] Solving $\delta = \delta^*(b, v)$ for b yields the positive root of a quadratic; the closed form is available on request but (16) is typically more transparent for comparative statics.

1. Higher forward trade and invoice values on buyback links. Under (10), buybacks increase order quantities and therefore forward trade: $q^B(b) - q^0 > 0$ with $\partial(q^B - q^0)/\partial b > 0$. Because buybacks also raise the per-unit invoice price to $w_b = w + b(1-\mu)$, forward invoice value $F(b) \equiv w_b q^B$ is increasing in b:

$$\frac{\partial F}{\partial b} = q^0 \, \frac{2w + (1-\mu)(1+b)}{(1-b)^3} > 0.$$

2. State-contingent reverse flows that activate in downturns. Returns equal the unsold quantity, $R(d) \equiv (1-d)q^B$. Thus returns are countercyclical in demand realizations: $\partial R/\partial d = -q^B < 0$. Moreover, more generous refunds increase reverse flows through larger orders:

$$\frac{\partial R}{\partial b} = (1-d)\frac{\partial q^B}{\partial b} = (1-d)\frac{2q^0}{(1-b)^3} > 0.$$

Expected returns satisfy $\mathbb{E}[R(d)] = (1-\mu)q^B$, so $\partial \mathbb{E}[R]/\partial b = (1-\mu)\partial q^B/\partial b > 0$.

3. Buybacks concentrate where informal enforcement is feasible. Because refunds are informal, buybacks are feasible only when relational incentives can sustain them. Under (16), feasibility expands with the supplier's continuation value and outside options: $\delta^*(b, v)$ is decreasing in $(w-c)$ and v. Hence buybacks should be more prevalent (and more likely to be honored in bad times) when suppliers have (i) stronger relational capital/longer horizons (higher effective δ), (ii) higher ongoing per-unit rents (higher $w - c$ and/or larger baseline trade), and (iii) greater redeployability/outside options (higher v). The model also implies a natural complementarity: when redeployability is low (high specificity), enforcing a given refund requires a larger shadow of the future.

4. Capacity–need matching (selection and honoring). On the *customer* side, the value of insurance is increasing in demand risk and in effective risk exposure. Under (7), expected profits at a fixed scale are unchanged (8) while variance falls by (11); thus the certainty-equivalent gain from adding a refund b at scale q is

$$\Delta U(q) = U_C^B(q) - U_C^0(q) = \frac{\gamma}{2}\alpha^2 \, q^2 \sigma^2 (2b - b^2),$$

which is increasing in σ^2, γ, and α. This yields a selection prediction: *riskier buyers* (higher demand volatility) and buyers with higher effective risk exposure have stronger incentives to adopt buybacks. On the *supplier* side, honoring buybacks requires both relational incentives and the capacity to absorb and redeploy inventory. The feasibility condition (16) shows that higher per-unit rents $(w - c)$ and higher redeployability v lower the patience required for self-enforcement, making buybacks easier to sustain. Combining both sides yields a matching prediction: buybacks (and especially honoring in downturns) should concentrate in dyads where *high-need buyers* (high demand risk) pair with *high-capacity suppliers* (high continuation value and strong redeployability/outside options).

OA.6 Extension: defect returns vs. inventory buybacks

This extension distinguishes *verifiable* defect/warranty returns from *non-verifiable* unsold-inventory buybacks. After the customer orders q, product quality is realized: a fraction $x \in [0, 1]$ of delivered units is defective. Defective status is verifiable (inspectable), so the associated refund is contractible. The customer returns xq, and the remaining $(1-x)q$ units are saleable. Demand then realizes via d as before. Let b_D denote the enforceable per-unit refund for defective units and b_U the (informal) per-unit refund for unsold saleable units.

Under spot wholesale price w, customer profit is

$$\pi_C^0(q, d, x) = d(1 - x)q - wq + b_D xq,$$

and under buybacks (w_b, b_U),

$$\pi_C^B(q, d, x) = d(1 - x)q - w_b q + b_D xq + b_U(1 - d)(1 - x)q.$$

Observed returns therefore decompose into defect returns xq (verifiable, contractible) and unsold-inventory buybacks $(1-d)(1-x)q$ (non-verifiable, relational). Only the second component generates a relational enforcement constraint. In particular, the supplier's deviation gain from refusing the unsold-inventory refund in state (d, x) is $(b_U - v)(1 - d)(1 - x)q^B$, and the worst-case IC again occurs at low d and low x.

Two implications follow. First, unsold-inventory buybacks are countercyclical in demand: for given q and x, $\partial[(1-d)(1-x)q]/\partial d = -(1-x)q < 0$. Second, defect returns are not me-

chanically tied to demand shortfalls. If x is roughly independent of aggregate demand, defect returns scale primarily with shipped quantity (and hence are procyclical with throughput), while the buyback component activates disproportionately in downturns. Because defect refunds are contractible, they should also be much less sensitive to relational-capital proxies than the non-verifiable buyback component (Hart, 1995; Tirole, 1999; MacLeod and Malcomson, 1989).

OB Alternative Interpretations

In this section, we consider alternative interpretations that could yield two-way invoicing in principle. Before we consider these alternatives, we first establish the core empirical patterns that any mechanism must be able to jointly rationalize:

1. *Shock-aligned timing:* reciprocal flows in treated dyads rise discretely at the onset of COVID, with no comparable divergence in earlier years, and no analogous spike among balanced controls (Figures 3–4).

2. *State-contingent substitution:* treated dyads exhibit a reversal in net flow direction —reciprocal (customer-to-supplier) sales increase while forward (supplier-to-customer) sales decline relative to controls—consistent with exercising a return option rather than expanding ordinary bilateral exchange (Table 6).

3. *Intermittency in normal times:* pre-COVID reciprocity is sporadic and modest in size (Table 1), consistent with a contingent backstop rather than routine two-way trade.

4. *Final-demand gradient:* activation is strongest in consumer-facing links (retail/wholesale; Table 7), where unsold-inventory insurance is most valuable.

5. *Supplier redeployment:* suppliers receiving larger reciprocal inflows subsequently expand sales through other customer links, first on the intensive margin and then by forming new outlets (Table 6, Panel B; Figure 5), consistent with reallocating resellable goods rather than booking purely financial transfers.

We use these signatures—together with targeted robustness checks—to assess alternative interpretations of reciprocal VAT flows.

OB.1 Opportunism (channel stuffing followed by returns)

If reciprocal flows mainly reflected opportunism, we would expect elevated activity outside the COVID period and less systematic alignment with a sharp negative demand shock. Instead, reciprocal flows spike tightly with the COVID collapse (Signature 1), while pre-pandemic reciprocity is intermittent and modest (Signature 3). Moreover, honoring concentrates among suppliers with greater shock-absorbing capacity (Table 9), consistent with state-contingent insurance rather than systematic manipulation.

OB.2 Ordinary two-way trade in unrelated goods or services

Two-way invoicing could reflect ordinary bilateral trade (e.g., goods exchanged for logistics, advertising, or other services). However, routine cross-purchases should be broadly procyclical or at least comove with overall activity; they would not naturally generate a sharp *substitution* pattern in which reciprocal flows rise as forward flows fall precisely when demand collapses (Signatures 1–2). The intermittency of reciprocity in normal times (Signature 3), its strongest activation closest to final demand (Signature 4), and the supplier-side redeployment patterns (Signature 5) are also difficult to reconcile with stable service procurement.

OB.3 Commercial adjustments (rebates, price protection, stock-rotation credits)

Reciprocal invoices might proxy for commercial adjustments recorded as the customer selling an offsetting service. While such practices exist, they are unlikely to account for our results. Adjustment settlements are typically tied to pricing cycles, promotions, or contractual true-ups and would not naturally generate the discrete, shock-aligned reversal at COVID (Signatures 1–2). More importantly, the supplier-network response—redeploying goods through other downstream links (Signature 5)—fits inventory reallocation but not financial transfers. Finally, our measurement choices explicitly distinguish reversing credit notes from positive reverse-direction sales and require strictly positive invoices in both directions (Section 3).

OB.4 Distress liquidation without a pre-committed buyback

COVID-period reverse sales could reflect ad hoc liquidation, with customers selling excess stock back to suppliers absent any prior commitment. This mechanism would predict that many previously one-way dyads begin showing reverse sales during the shock. Instead, the reversal is concentrated in dyads with pre-COVID reciprocity, because treatment is defined using only 2017–2019 behavior and then held fixed (Signatures 1–3). The stronger effects in consumer-facing links (Signature 4) and subsequent supplier redeployment (Signature 5) also align more naturally with anticipated returns than one-off liquidation.

OB.5 Intra-group inventory shifting

Reciprocal flows might reflect internal reallocations within business groups (transfer pricing or inventory shifting across affiliates). Such transfers are typically stable and would not naturally generate a sharp, state-contingent break at COVID (Signatures 1–2), especially once dyad fixed effects and partner-by-year fixed effects net out persistent within-pair patterns and common firm-year shocks. More directly, our estimates are unchanged when excluding within-group transactions using affiliate identifiers from the Fair Trade Commission's large business group portal.[25]

OB.6 Reverse logistics, packaging, scrap, and byproduct buybacks

Finally, reciprocal flows could reflect closed-loop logistics (packaging returns, scrap/byproduct buybacks) rather than returns of unsold goods. Closed-loop flows are typically tied to throughput and thus should fall when demand collapses; they do not predict a substitution pattern in which reverse flows rise as forward flows fall (Signatures 1–2). The intermittency of reciprocity in normal times (Signature 3), the strong final-demand gradient (Signature 4), and the supplier redeployment evidence (Signature 5) all point away from routine recycling/logistics streams as the primary driver.

Overall, while no single diagnostic is definitive, the *joint* pattern of (i) shock-aligned activation, (ii) substitution between forward and reverse flows, (iii) intermittent pre-COVID

[25] `www.egroup.go.kr/egps/wi/info/aboutGroupPage.do`

use, (iv) stronger effects near final demand, and (v) systematic supplier redeployment is difficult to reconcile with alternative mechanisms. Any remaining misclassification in our proxy would tend to attenuate differences across groups, rendering our estimates conservative.

Figure OB1: Sector-level post-shock change in reciprocal sales by buyback status.
For each sector (Korean Standard Industrial Classification first letter), the figure plots the percentage change in a dyad's average quarterly sales from the pre-COVID period (2017Q1-2019Q4) to the COVID period (2020Q1-2021Q4). Blue markers indicate reciprocal (customer-to-supplier) sales for buyback dyads, and red markers forward (supplier-to-customer) sales for non-buyback dyads whose reciprocal flows are zero by construction. Buyback status and role assignment follow Figure 1.

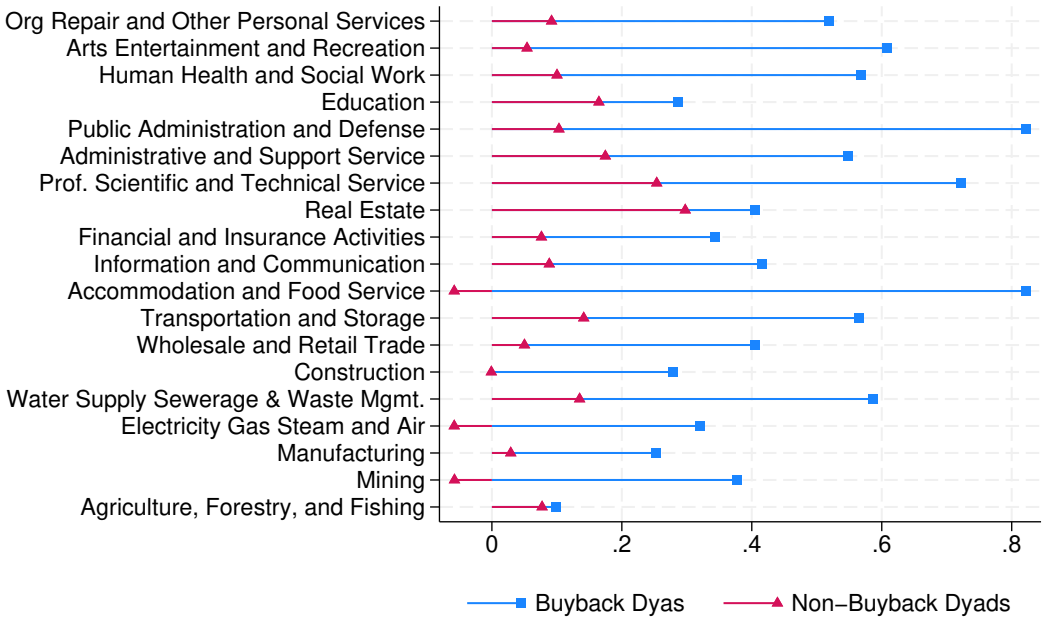


Figure OB2: Self-enforcement and redeployability (Implications 3 and 4). The maximal sustainable refund increases with relationship continuation value (δ) and shifts up when returned goods are more redeployable (higher v), because reneging becomes less attractive and honoring is less costly. Parameter values ($w-c = 0.2$, $\mu = 0.8$) are illustrative.

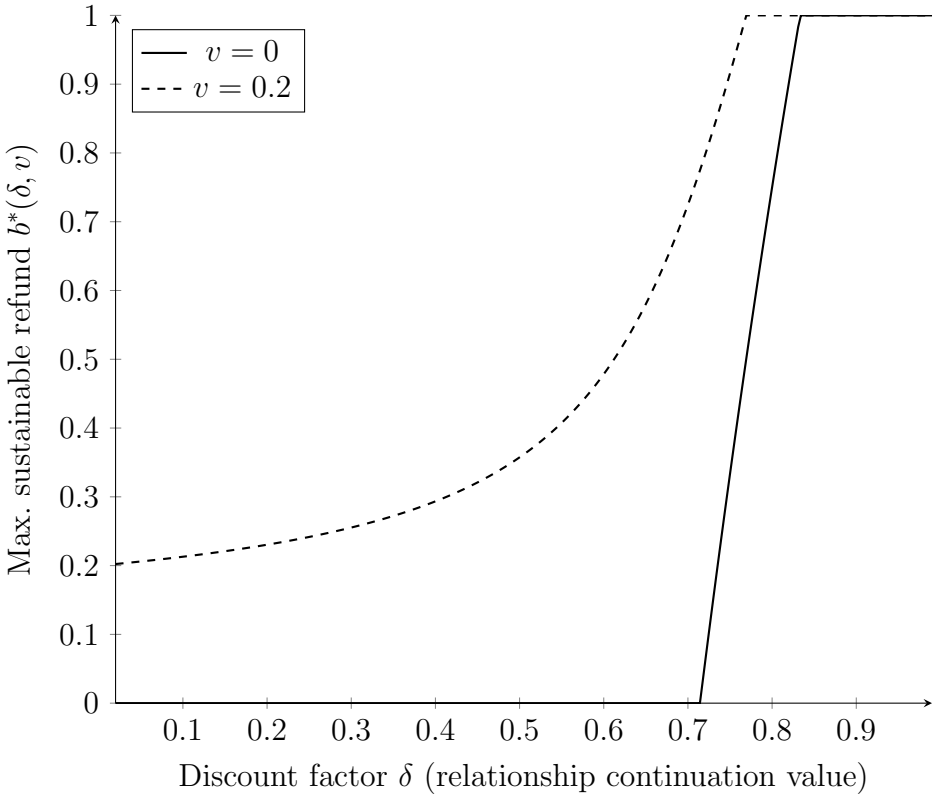


Table OB1: Entropy balancing diagnostics for reciprocal sales outcome.
The table compares buyback (treated) and non-buyback (control) dyads before and after entropy balancing when the outcome is *Log Reciprocal Sales* (Figure 4). Controls are reweighted to match treated means on pre-COVID (2017Q1-2019Q4) covariates – dyad attributes, customer and supplier firm characteristics (measured in 2019), and customer and supplier industry indicators – plus year-to-year changes in the outcome. For each covariate, we report, before weighting (Columns 1-4), the treated mean $\bar{X}_T$, control mean $\bar{X}_C$, difference $\bar{X}_T - \bar{X}_C$, and the variance ratio $\text{Var}(X_T)/\text{Var}(X_C)$; and after weighting (Columns 5-6), the treated-reweighted control difference $\bar{X}_T - \bar{X}_C^w$ and $\text{Var}(X_T)/\text{Var}(X_C^w)$. ESS denotes the effective sample size implied by the weights. See Table A1 for variable definitions.

	(1)	(2)	(3)	(4)	(5)	(6)
			Pre- Balancing (ESS: 1,289,370)		Post-Balancing (ESS = 763,958)	
	$\bar{X}_T$	$\bar{X}_C$	$\bar{X}_T - \bar{X}_C$	$\frac{\text{Var}(X_T)}{\text{Var}(X_C)}$	$\bar{X}_T - \bar{X}_C^w$	$\frac{\text{Var}(X_T)}{\text{Var}(X_C^w)}$
Dyad characteristics						
Log Transacting Qtr.	2.16	2.16	0.01	1.14	0.00	1.10
Log Consecutive Transacting Qtr.	1.83	1.82	0.02	1.12	0.00	1.08
Log Distance	2.94	3.42	-0.48	0.84	0.00	0.95
Customer characteristics						
Log Assets	15.69	15.83	-0.14	1.15	0.00	1.10
Log Firm Age	2.38	2.44	-0.06	1.03	0.00	1.04
Debt to Assets	0.57	0.54	0.03	1.12	0.00	1.12
Return on Assets	0.06	0.06	0.00	1.12	0.00	1.20
Asset Turnover	1.92	1.65	0.26	0.80	0.00	1.15
Log CEO Age	3.99	4.01	-0.02	0.97	0.00	1.03
Supplier characteristics						
Log Assets	17.08	16.74	0.34	1.04	0.00	1.08
Log Firm Age	2.51	2.59	-0.08	0.89	0.00	1.08
Debt to Assets	0.57	0.51	0.05	0.92	0.00	1.11
Return on Assets	0.05	0.08	-0.02	0.93	0.00	1.10
Asset Turnover	1.85	1.54	0.30	0.66	0.00	1.23
Log CEO Age	3.99	4.02	-0.03	0.95	0.00	1.01
Outcome variable changes						
$\Delta_{[2018,2019]}$ Log Reciprocal Sales	-0.03	-0.04	0.01	0.64	0.00	0.71
$\Delta_{[2017,2018]}$ Log Reciprocal Sales	0.10	0.11	0.00	0.66	0.00	0.73

Table OB2: Robustness to variable definitions, weights, and sample.
The table replicates the baseline estimates in Table 6 (Panel A, Columns 1 and 5) under alternative specification choices. In Panel A, Columns 1-2 replace the outcomes with *Log Reciprocal Sales per Invoice* and *Log Forward Sales per Invoice* (log of one plus value divided by invoice count); Columns 3-4 redefine *Buyback* to equal one when the dyad records positive reciprocal sales in at least two pre-COVID quarters (2017Q1-2019Q4). In Panel B, Columns 1-2 drop entropy-balancing weights; Columns 3-4 exclude electronics (Korean Standard Industrial Classification (KSIC) C26) and automobiles (KSIC C30) from the sample. Definitions of *Post*, *Buyback*, *Log Reciprocal Sales*, and *Log Forward Sales* follow Table 6; dyad types and role assignment follow Figure 1. Standard errors are two-way clustered by supplier and customer. *, **, and *** denote significance at the 10%, 5%, and 1% levels, respectively.

Panel A. Alternative variables

	(1)	(2)	(3)	(4)
	Alternative Outcome Definition		Alternative Buyback Definition	
	Log Reciprocal Sales per Invoice	Log Forward Sales per Invoice	Log Reciprocal Sales	Log Forward Sales
Post × Buyback	0.0490***	-0.0493***	0.104***	-0.0517***
	(0.00443)	(0.00267)	(0.00942)	(0.00510)
Dyad FE	✓	✓	✓	✓
Cus. × Year FE	✓	✓	✓	✓
Sup. × Year FE	✓	✓	✓	✓
Adj. R^2	0.916	0.893	0.906	0.880
N	6,162,543	6,609,857	6,162,543	6,609,857
Buyback = 1 for *bbb* and 0 for *bbn, bnn, nbn* and *nnn*				

Panel B. Alternative weighting and sample

	(1)	(2)	(3)	(4)
	W/O Entropy Weight		Excluding Automobile & Electronics	
	Log Reciprocal Sales	Log Forward Sales	Log Reciprocal Sales	Log Forward Sales
Post × Buyback	0.122***	-0.0889***	0.109***	-0.0400***
	(0.00856)	(0.00398)	(0.00983)	(0.00465)
Dyad FE	✓	✓	✓	✓
Cus. × Year FE	✓	✓	✓	✓
Sup. × Year FE	✓	✓	✓	✓
Adj. R^2	0.891	0.893	0.905	0.880
N	6,162,543	6,609,857	5,911,677	6,336,161
Buyback = 1 for *bbb* and 0 for *bbn, bnn, nbn* and *nnn*				

Table OB3: Determinants of buyback formation for dual supplier-customer firms.
The table reports linear probability models for $\mathbb{1}$(*Dual-Role Buyback Firm*), which equals one if, in its pre-COVID production network (2017Q1–2019Q4), the firm appears in at least two distinct buyback dyads, acting as a supplier in one and as a customer in another. Buyback status and role assignment follow Figure 1. Covariates measured in 2019 follow Table 8, Panel B. Standard errors in parentheses are heteroskedasticity-robust in Column 1 and clustered by industry in Column 2. *, **, and *** denote significance at the 10%, 5%, and 1% levels, respectively.

	(1)	(2)
	$\mathbb{1}$(Dual-Role Buyback Firm)	
Sales Growth Volatility	0.0084***	0.0100***
	(0.001)	(0.002)
Log Assets	0.1466***	0.1502***
	(0.001)	(0.008)
Log Firm Age	-0.0372***	-0.0377***
	(0.001)	(0.006)
Debt to Assets	0.0254***	0.0243***
	(0.001)	(0.002)
Return on Assets	-0.0428***	-0.0394***
	(0.001)	(0.004)
Asset Turnover	0.0425***	0.0437***
	(0.001)	(0.008)
R&D to Sales	0.0264***	0.0236***
	(0.001)	(0.003)
Log Patent Counts	0.0252***	0.0170***
	(0.001)	(0.003)
Log CEO Age	-0.0246***	-0.0253***
	(0.001)	(0.004)
Unique partners per firm	0.0929***	0.0896***
	(0.001)	(0.007)
Partner HHI	-0.1329***	-0.1217***
	(0.002)	(0.005)
Partner (2-digit) Ind. HHI	0.0043***	-0.0085
	(0.002)	(0.010)
Partner (within 2-digit, 3-digit) Ind. HHI	0.0184***	0.0188***
	(0.001)	(0.006)
Industry FE		✓
Adj. R^2	0.3541	0.3804
N	203,091	203,090

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