Technology, Contracts, and Coordination: Modernizing Agricultural Supply Chains in Wisconsin Potatoes

Nurlan Utesov (UW-Madison)   Paul Mitchell (UW-Madison)

September 30, 2025

Abstract

This paper examines how technology adoption and contractual coordination jointly shape modernization in agricultural supply chains. Using a detailed case study of the Wisconsin fresh potato industry from 2010 to 2019, we analyze the effects of a wholesaler's investment in quality-enhancing technology—specifically optical sorting systems (OSS)—and the establishment of long-term marketing contracts with a modern retail chain. Employing a structural demand model and a difference-in-differences strategy, we find that technological innovation increased price-cost margins by 4.6 cents per pound ($\tilde{1}0\%$), while marketing contracts contributed an additional 1.5 cent increase. These gains were reinforced by improved inventory management and reduced spoilage, underscoring the role of coordinated investments and formal agreements in enhancing efficiency. Our findings highlight how both relational foundations and formal contracts can align incentives in quality-sensitive, vertically fragmented markets. By providing rare empirical evidence from a developed-country context, this study contributes to the literature on supply chain modernization and demonstrates how technology and contracts together drive performance in agriculture.

1 Introduction

In demand-driven agricultural industries, the ability to adapt to shifting consumer preferences is a critical determinant of firm success. Such adaptation often requires upstream and midstream actors in the supply chain to make large, sunk-cost investments in product quality, creating the potential for classic hold-up problems (Williamson 1975; O. Hart and Moore 1990). When downstream firms hold property rights or bargaining power over a product, upstream suppliers may underinvest in quality-enhancing technologies because much of the surplus can be appropriated by the downstream partner. Vertical integration can mitigate this underinvestment problem by internalizing transactions (Coase 1993; Gibbons 2005; Lafontaine and Slade 2007), but integration may also distort incentives when property rights are poorly specified. Incomplete contracting and hybrid governance structures may therefore provide more efficient solutions (Grossman and O. D. Hart 1986; O. Hart and Moore 1990).

A central question is how to align incentives in environments where quality monitoring is costly, investment decisions are non-contractible, and consumer demand increasingly requires higher product quality (Baker et al. 2001; Baker et al. 2002; Holmstrom and Milgrom 1991; Hansman et al. 2020). Relational contracts—self-enforcing agreements based on repeated interaction and reputation—offer one mechanism for sustaining cooperation when quality monitoring is limited (Telser 1980; Klein and Leffler 1981). Their continuation value can support investments that would otherwise be vulnerable to opportunism. This is especially important in trial investment environments, where both parties face uncertainty about the returns to quality-enhancing efforts. In such cases, relational governance allows firms to experiment with new practices or technologies while relying on mutual trust to share risks and adjust expectations over time(Lerner and Malmendier 2010; Bloom et al. 2007; Abel 1983). At the same time, formal long-term marketing contracts can complement relational mechanisms by stabilizing prices, reducing uncertainty, and facilitating coordination with downstream retailers(Poppo and Zenger 2002; Macchiavello and Morjaria 2023).

This paper examines how technology adoption and contractual coordination jointly modernize agricultural supply chains. We focus on the Wisconsin fresh potato industry between 2010 and 2017, where a local wholesaler invested in quality-enhancing technologies—most notably optical sorting systems (OSS), expanded storage, and improved logistics—and subsequently entered into long-term marketing contracts with a modern retail chain. These institutional and technological changes provide a unique opportunity to study how modernization reshapes incentives and performance in a vertically fragmented, quality-sensitive market.

Our empirical strategy exploits variation across products and time in both technology adoption and contractual arrangements. Using a flexible demand estimation framework based on a random coefficients logit model(Berry et al. 1993) and a difference-in-differences framework, we estimate product-level elasticities and recover price-cost margins. Preliminary results suggest that adoption of OSS reduced marginal costs by approximately 4.6 cents per pound (~10% of the price), while the introduction of formal marketing contracts contributed an additional 1.5 cent increase in price-cost margins. These gains were reinforced by improved inventory management and reduced spoilage, highlighting the complementarity between technological investments and contractual coordination.

The broader U.S. agricultural sector provides important context. In the hog and cattle industries, large-scale investments in genetics, feeding technologies, and processing facilities have been closely tied to the rise of production and marketing contracts, which align incentives between growers and processors (MacDonald and Korb 2004; MacDonald and Key 2013). In poultry, the integration of growers into processor-controlled supply chains has been accompanied by substantial processor investments in hatcheries, feed mills, and vertically coordinated processing plants, enabling efficiency gains and quality control (Key and McBride 2004; MacDonald 2014). Similarly, in fruit and vegetable markets, adoption of optical sorting, controlled-atmosphere storage, and precision grading technologies has improved consistency, reduced waste, and supported branding strategies (Calvin 2004; Roberts and Schlenker 2016; Pawelec 2024). USDA reports emphasize that such investments have been critical for maintaining year-round supply and meeting retailer quality standards in perishable commodities, including potatoes (USDA Economic Research Service 2020; USDA National Agricultural Statistics Service 2024).

By situating the Wisconsin potato case within this broader context, our study contributes to the literature on supply chain modernization. We show how relational foundations and formal contracts can jointly support technology adoption, align incentives, and improve market outcomes. At the same time, we acknowledge that close coordination may also create risks of reduced competition, as past collusion cases in the potato industry illustrate[1][2]. Understanding these trade-offs is essential for evaluating the role of contracts and technology in modernizing agricultural supply chains.

[1] https://www.courthousenews.com/potato-cartel-settles-for-25-million/
[2] https://www.hbsslaw.com/cases/frozen-potato-products-antitrust

2 Determinants of Potato Quality

This section describes some of the key features of Wisconsin's fresh potato industry, including seasonality, storage, transportation, grading-sorting technology, and relational contracts. These features are important for understanding the relationships inside the supply chain, the capacity to provide a stable supply of high-quality products and institutional difference in the market segmentation on commodity and specialty varieties. Lastly, we describe the real example of how all these play a role in the development of a new local brand.

2.1 Sector Overview

The potato industry in the United States is highly developed and marked by remarkable productivity among farmers, for example, the nation's average yield was 44.3 metric tons per hectare in 2024 (U.S. Department of Agriculture, National Agricultural Statistics Service 2024). Among US states, Wisconsin is the third-largest potato producer, generating a farm-gate value of $439 million in 2023(U.S. Department of Agriculture, National Agricultural Statistics Service 2023). Fresh potatoes account for the largest share of this total in Wisconsin, around 40%, with processing, chipping and seed potatoes accounting for the remaining share (U.S. Department of Agriculture 2024).

Consumption patterns for fresh potatoes in the United States have continued to evolve, reflecting a broader shift toward more convenient and easily prepared foods. In 2010, per capita consumption of fresh potatoes in the U.S. was 21.4 kg, but by 2019 it had declined to 15.5 kg. During the same period, the share of processed potatoes in total consumption rose from 66% to 71% (U.S. Department of Agriculture, Economic Research Service 2020). Today, the primary challenge facing the U.S. fresh potato industry is not production capacity, but rather effective marketing and the ability to meet consumer demand for high-quality, convenient products[3].

2.2 Product Differentiation and Quality

The fresh potato supply chain consists of three main parts: farmers who grow potatoes; wholesalers (also called shipper/packers) who clean, grade, package, and transport potatoes; and retailers who usually have multiple grocery stores in retail chains that sell potatoes to consumers. As the retailer chains do net have their own shed packing facilities, so they buy bagged potatoes from different wholesalers. Ensuring that consumers consistently receive high-quality potato products all year requires coordination among all three parts of the supply chain. If a farmer neglects key steps such as planting certified seed potatoes, using recommended crop management practices, or appropriately managing long-term storage, the crop becomes significantly more vulnerable to a range of diseases or disorders that cause crop or quality loss. Certified seed potatoes are required to meet strict standards to ensure they are free from major pathogens like bacterial ring rot, soft rot, and late blight tuber rot (U.S. Department of Agriculture, Agricultural Marketing Service 2024). Poor nutrient, pest or irrigation management contributes to multiple crop disorders or injury that can lead to conditions like misshaped tubers or hollow heart (Yi Wang 2025). Additionally, storage management requires maintaining proper temperature and humidity and regular monitoring to determine if and when to use post-harvest control agents that reduce the risk of disease outbreaks that can rapidly reduce tuber quality (U.S. Department of Agriculture, National Agricultural Library 2024). Nevertheless, even with proper management, diseases or other problems can occur in the field or in storage. However, effectively monitoring grower management of multiple large fields over a season or placement of thousands of tons of potatoes into storage is too costly. Mismanagement makes it nearly impossible for a wholesaler to ensure long-term storage over several months in order to maintain a year-round consistent product supply to retailers. A com-

[3]https://www.nass.usda.gov/Publications/Todays$_{R}eports/reports/potsum15.pdf$

mon strategy for creating high-quality brand in the fresh produce industry involves making investments in up-to-date sorting, storage, and logistics technologies in combination with developing long-term informal relationships based on trust and reputation.

2.3 Effects of Optical Sorting Systems

Optical Sorting Systems (OSS) are advanced machinery that utilize multi-spectral imaging (e.g., X-rays), lasers, and image processing algorithms to sort solid products based on physical attributes such as color, shape, size, and even chemical composition. In the fresh produce industry, OSS technology enables precise classification of individual fruits and vegetables—not only by size but also by detecting internal defects that are invisible to the human eye.

Recent advances in optical sorting and grading have significantly transformed post-harvest handling of fruits and vegetables (Rady and Guyer 2015; Pedreschi et al. 2016). Commercial OSS platforms are now widely adopted in the potato industry, particularly among packers and processors, to rapidly assess tuber dimensions and weight. Increasingly, field researchers also employ these systems to collect individual tuber data from experimental plots (Stockem et al. 2022; Crosby and Y. Wang 2021). As commercial adoption grows, OSS use in field research is expected to expand, especially as empirical workflows integrate high-resolution phenotyping with structural modeling approaches.

In the fresh potato sector, OSS can replace traditional manual and mechanical sorting, substantially lowering marginal sorting costs. However, the high fixed costs of OSS require sufficient throughput to ensure profitability. The technology also facilitates quality improvements that enable wholesalers to command price premiums, supporting cost recovery.

Beyond operational efficiency, OSS generates detailed quality distribution reports that allow wholesalers to differentiate products and assign prices based on quality (Sexton

2013). This transparency incentivizes farmers to adopt improved field practices and inputs that enhance storage capacity and overall product quality. Ultimately, OSS aligns incentives across the supply chain, helping wholesalers consistently deliver high-quality produce year-round.

2.4 Market Structure

Figure 1 presents a simplified representation of the Wisconsin fresh potato industry. This structure stands in contrast to a fragmented supply chain, where production, processing, distribution, and retailing are handled by numerous independent and often uncoordinated entities. Such fragmentation typically leads to inefficiencies, lack of transparency, and misaligned incentives across the supply chain (Caputo and Reardon 2025; Essien et al. 2023; Straight 2025)..

In Wisconsin, the upstream segment of the fresh potato industry consists of more than a hundred commercial growers producing multiple potato varieties. Most growers maintain long-standing, informal yet stable relationships with a small number of wholesalers—commonly referred to as packing sheds or shipper-packers. There are approximately twenty potato packing sheds in the state, though most are relatively small. Three of them ship 5,000 or more semi-trailer loads annually, and four ship between 2,000 and 4,000 loads[4]. These packing sheds are almost exclusively owned by growers who pack and ship their own potatoes, while also serving growers without sheds. The relationships between growers and packers often span generations, and switching between sheds is rare—indicating a high degree of implicit coordination and trust. Among these growers, eight large producers (one of whom also owns a major packing shed) have formed a strategic partnership to launch a high-quality local brand that we call new local brand.

The relationship between wholesalers and retailers in Wisconsin can be broadly cat-

[4] https://wisconsinpotatoes.com/wp-content/uploads/2025/01/WI_Potato_Directory_2025_v1.pdf

egorized into two patterns (Figure 1). Traditional retailers typically rely on spot market transactions using brokers to source fresh potatoes year-round without long-term commitments to any individual wholesaler. In contrast, a modern retailer has developed an enduring partnership with the new local brand, supported by formal marketing contracts. In the produce sector, these longer-term marketing contracts are often tied to the adoption of quality-enhancing technologies, such as an optical sorting system (OSS) and reflect a shift toward greater vertical coordination(Asirvatham and Bhuyan 2018).

The section 4 provides further detail on the technological investments made by the new local brand on the farm and packing shed level, the transition from informal to formal contracts, and how these changes have reshaped relationships and incentives within the supply chain.

2.4.1 Market Segmentation

Wisconsin fresh potato farmers grow multiple potato varieties, but the market can be roughly divided into two segments – commodity and specialty varieties – each with different organizational structures.

The commodity segment consist mainly of Russet and large, A-size red potato varieties[5] and in total account for about 75% of the fresh potato sales in the Wisconsin retail market (authors' computation). The local supply of fresh Russet potatoes is seasonal. Figure 2 shows that the monthly movement (millions of pounds) of fresh Russet potatoes shipped by wholesalers from Central Wisconsin(U.S. Department of Agriculture, Agricultural Marketing Service 2025b). Movement significantly decreases in August when wholesalers clear storage facilities in preparation for the new crop, and steadily increases until October-November as potato harvest progresses in Wisconsin. Movement then slowly declines as wholesalers ship potatoes out of storage. Overall, given large

[5] A-size means the tubes averaging about 2.5 inches in diameter and 6 ounces(U.S. Department of Agriculture, Agricultural Marketing Service 2024)

number of Russet potato farmers in the US, the commodity segment is relatively competitive, featuring substantial price and sales volatility, with national price trends mostly determined by production in Idaho, the largest potato producing state.

Compared to commodity Russet production, fewer Wisconsin farmers grow specialty varieties, such as a baby, small size (B-size) red, and yellow or creamer varieties. Specialty potatoes growers must use more costly field and storage practices to meet high appearance and quality standards for these varieties, and rejection occurs more often than for commodity (Russet) varieties. With the high potential benefits and risk, ex-ante (before planting) relational contracts between a farmer and a wholesaler are common in these markets. The marketing contracts between a wholesaler and a retailer also have a reputational aspect and are often negotiated 2-3 weeks before the beginning of harvest (often in late July). As a result, the in-store retail price stabilize after harvest and remain stable until January-February when the local storage is depleted and Wisconsin wholesalers must switch to shipping in specialty varieties from other states to satisfy retail contracts.[6] Figure 3 shows the resulting seasonality of the local red potato wholesale shipping volumes. Movement data from central Wisconsin show no local supply is available to wholesalers during the February- July period, whereas the volume outside Wisconsin is still substantial(U.S. Department of Agriculture, Agricultural Marketing Service 2025b).

Volume dynamics also show a similar pattern at the retail level in our data. Figure 4 shows the volume and price dynamics for premium red variety. Usually the volume spikes happen in Wisconsin retailers when the local supply of red potatoes is unavailable from February to July and wholesalers must ship in product from other states at higher cost than the local supply. Furthermore, as the new harvest of winter potatoes in Florida and California starts in April, consumers prefer freshly harvested potatoes shipped in from these regions to local red potatoes in storage since the previous fall. As a result, during this non-

[6]Based on interviews, Wisconsin farmers struggle to store red varieties past February due to increasing occurrence of storage diseases and defects

local supply period, market shares and prices of the specialty potatoes are simultaneously increasing.

Figure 5 presents the price–volume relationship for potato varieties in Wisconsin between 2010 and 2017, aggregated across the state's three largest retailer chains using Nielsen Retail Scanner data. Russet products exhibit a consistently negative slope across the price range, with the exception of items priced above 70 cents per pound. In contrast, premium small red potatoes (B size) and standard red potatoes (A size) with prices exceed 70 cents per pound display a positive slope once. This pattern highlights substantial heterogeneity within variety groups and suggests that further segmentation based on product premiality is necessary to capture meaningful differences across varieties. Overall, the results indicate that consumers purchasing specialty varieties are less sensitive to price changes.

3 Data

We use four primary data sources: the Nielsen Retail Scanner Data(Nielsen Company 2022), USDA shipping point price data for central Wisconsin(U.S. Department of Agriculture, Agricultural Marketing Service 2025a), and USDA movement data for central Wisconsin(U.S. Department of Agriculture, Agricultural Marketing Service 2025b). In next section we describe the data and how it was prepared for estimation.

3.1 Retail Data

Nielsen's Retail Scanner Data (RMS) tracks fresh potato purchases from retail chains with annual sales exceeding $2 million, using point-of-sale terminals. This dataset includes weekly pricing, volume, and store environment information for all bagged potato products with Universal Product Codes (UPCs). Note that these data do not include items sold by weight or count using price look-up (PLU) codes.

Another Nielsen dataset, the Consumer Panel Data (HMS), provides insights into consumer purchasing behavior by tracking the purchases of a representative panel of households over time. Panelists use in-home scanners to record all purchases intended for household consumption, offering a comprehensive view of shopping habits. HMS data helps validate that consumption trends observed in RMS data reflect actual consumer behavior. For the Wisconsin household data analyzed here, approximately 30% of HMS fresh potato purchases occurred outside of RMS-covered stores, as some major retail chains are not included in RMS. Nevertheless, HMS data confirms that consumers' shift toward higher-quality products aligns with trends observed in RMS.

3.2 Wholesaler Data

The USDA AMS provides information related to agricultural markets, including the movement and prices for potato varieties shipped from major wholesaler shipping points, including Central Wisconsin. We use USDA-AMS shipping point prices (SPP) as a proxy for wholesale prices. SPP are the prices paid by retailers at the location where they are first packed and shipped, reported as FOB ("Free On Board") to indicate that the price includes the cost of the product and any costs up to the point of shipment, but excludes the cost of transportation to the buyer. SSP data include prices by potato variety, grade, size, and package type. Based on discussion with potato wholesalers in the region and USDA AMS personnel, these prices reflect open (or "spot") market prices and not prices paid as part of longer-term marketing contracts (these prices remain unreported). Hence, we use these SSP as a reasonable proxy for wholesale prices of commodity potatoes, since a significant portion of these varieties are often traded in the open-market.

3.3 Market Definition

We define a market unit as a unique combination of county, retail chain, year, month, and the 3-digit ZIP code of the store location. This structure allows us to adequately approximate household-level product choice probabilities. First, although potatoes are a staple food item, consumers' choice of retailer is primarily influenced by the overall assortment of products offered, rather than the price of a single item such as potatoes(Chernev and Hamilton 2009). Therefore, it is unlikely that marginal price differences in potatoes alone would drive store switching behavior. Second, our analysis of the Nielsen Consumer Panel Data (HMS) indicates that most households consistently buy groceries at the nearest retail chain, and switching between retailers is a relatively rare event.

3.4 Retail Chain Choice

We restrict RMS data analysis to fresh potato purchases in Wisconsin during the period 2010–2017 for the three largest retail chains in the RMS data. These three chains together account for more than 90% of total volume sales (measured in pounds) in the RMS data. Based on their largely non-overlapping product sets, we categorize these retailers into two groups: two 'traditional' chains (one large and one small), which primarily offer private-label or store-brand potatoes, and one 'modern' chain, which predominantly sells national and local brands. Next, to ensure stable estimates of market-level sales and to avoid modeling consumer retail choice directly, we exclude market units that have insufficient annual sales volume, have fewer than seven active stores, or display high volatility in year-to-year sales during the study period (2010-2017). We chose 2017 as the cutoff due to a structural change observed in the data beginning that year – the stores belonging to the small traditional chain according to their parent code changed their parent affiliation to the large traditional chain. We interpret this as evidence of a potential acquisition or merger between the national chain (likely Kroger) and the smaller 'traditional' retailer (likely the Pick'n'Save group)[7], which altered the composition of their stores and directly affected consumer retail choice probabilities.

3.5 Market Size

To define market size, we first compute total chain-level sales aggregated by retail chain, county, store 3-digit ZIP code, season (beginning in September each year), and month. We then define market size as the maximum monthly sales observed within each season. This approach is motivated by several considerations.

First, this definition captures the potential peak consumption of bagged fresh potatoes

[7] https://www.thenorthwestern.com/story/money/2015/11/11/kroger-buy-roundys-pick-n-save-parent/75572190/

within each market unit. As illustrated in Figure 6, the seasonal dynamics of fresh bagged Russet potato sales in retail chains closely mirror the total movement volumes reported in USDA AMS data (see Figure 2). Both series exhibit a trough in August—just before the local harvest—and a peak in October or November, following completion of harvest. This alignment suggests that retail chain sales are proportional to overall local Russet supply, implying that chains attract a consistent share of consumers over seasons.

Second, this market size definition provides a meaningful benchmark for the outside option in consumer demand. During peak supply months (October–November), when product quality is highest and availability is abundant, the outside option—defined as not purchasing potatoes—is likely at its lowest. Conversely, in late summer (July–August), when local supply diminishes and product freshness declines, the outside option becomes more attractive.

Finally, variation in peak seasonal sales across seasons and chain may reflect differences in harvest quality among the wholesalers that chains work with. A higher-quality harvest is likely to generate stronger consumer demand, leading to higher peak sales. Thus, our market size definition not only captures potential consumption but also embeds information about supply-side quality variation, which leads to adequately reflecting consumers' product choice probabilities.

3.6 Products

Between 2010 and 2017, the dataset includes over one hundred distinct UPCs for fresh potatoes. To ensure tractability and focus on the most relevant products, we restrict our analysis to the 43 most frequently purchased items, which together account for approximately 95% of total fresh potato sales across the three selected retail chains. The exclusion of low-frequency, low-volume products is driven by both empirical and computational considerations. Specifically, the presence of numerous infrequently observed UPCs with market shares close to zero introduces numerical instability in the estimation of product elasticities (see details in the empirical section). Properly modeling such products would require accounting for infrequent or dynamic retail supply(Ge et al. 2019), which is beyond the scope of this study. Importantly, the selected products represent over 80% of total volume sold (measured in pounds) in the selected chains, ensuring that the sample adequately reflects real market behavior.

3.7 Market Share and Price

To construct monthly market share estimates, we aggregate RMS data to the product-market-month level. A product's market share is defined as the ratio of its total monthly sales volume (in pounds) to the total market size within the corresponding market and month. Product prices are calculated as unit values, obtained by dividing total product revenue by total sales volume (in pounds) over the same period. Aggregating to the monthly level mitigates the volatility observed in weekly data, which often arises from irregular product availability in stores. Such volatility can introduce numerical instability and poses challenges for structural demand models like BLP, which may struggle to rationalize highly erratic or sparse observations. However, aggregating to the quarterly level risks losing important variation driven by seasonal supply-side shocks.

3.8 Product Characteristics

For the 43 selected products, we construct a set of product-level indicator variables to capture key attributes, including premium product, budget (low cost) product, red A-size, generic brand, local brand, national brand, and relevant interaction terms. This specification avoids multicollinearity issues associated with using unique product identifiers, particularly since products with identical UPC descriptions but differing package sizes (different last two UPC digits) often exhibit similar price-to-volume relationships. Moreover, these categorical indicators allow us to model substitution patterns more realistically, as products sharing similar observable characteristics tend to exhibit stronger substitution behavior. By nesting products within these characteristic-based groups, we improve the model's ability to capture consumer choices and cross-price elasticities.

Aggregation across these variants is not economically sensible, as price per pound can vary substantially—by as much as 10–20%—across different package sizes. Smaller bags are often priced at a premium, reflecting retailer strategies that encourage more frequent store visits while increasing per-unit margins. To account for this, we include separate indicator variables for each bag size (10 lb, 8 lb, 5 lb, and 3 lb), capturing both retailer pricing behavior and potential differences in packaging and distribution costs.

We further control for heterogeneity and increase data fit in consumer demographics and retailer strategies by including fixed effects at the county–ZIP code and retailer chain levels. These fixed effects help account for variation in the socio-economic composition of consumers that different chains attract in each market. Additionally, we include date fixed effects (at the season-month level) to control for common temporal shocks to supply and demand.

To account for the seasonal supply dynamics of red potato varieties, we include indicator variables for one and two months prior to the onset of the local harvest period (typically May–July). These indicator variables capture transitional periods during which recently harvested (new crop) red potatoes are shipped into Wisconsin from other regions and may temporarily dominate the market, as local stocks of old crop Russet potatoes approach the end of their storage period. Without controlling for this seasonal shift, the model would incorrectly attribute the observed increase in both price and sales volume during these months, resulting in a spurious positive price–quantity relationship. By explicitly modeling this pre-harvest window, we improve the model's ability to distinguish between supply-side constraints and genuine demand-side responses.

4 New Local Brand Development

In this section, we describe the implementation of quality-enhancing technological investments and their impact on supply chain relationships. These innovations were new to the industry, and stakeholders across the supply chain were initially uncertain about the potential surplus they could generate. We argue that relational contracts between farmers, shippers/packers, and retailers were a necessary condition for initiating trial investments.

We provide empirical evidence showing that once uncertainty was resolved, these contracts transitioned from short-term to long-term arrangements. This transformation is supported by information gathered during structured interviews with stakeholders involved in the industry.

4.1 Modernization and Strategic Growth of the Alsum Brand

The majority of Wisconsin fresh potato growers maintain long-standing relationships with four major local wholesalers (shippers-packers). Among them, we highlight one key wholesaler—Alsum Farms & Produce—as an early adopter of modernization within the state's fresh potato market. Alsum Farms & Produce (https://alsum.com/) is a vertically integrated Wisconsin-based potato grower and packer. Historically, the firm specialized in packing and shipping fresh Russet potatoes under national and customer-specific brands. However, during the 2010–2017 study period, Alsum began expanding its packing capacity and forming partnerships with local growers to develop and promote its own label, which we refer to as the 'new local brand' throughout this paper. The modernization of the new local brand involved a series of strategic investments in storage and sorting technology, marketing, and logistics infrastructure. We constructed the following timeline with key milestones during the 2010 to 2017 study period based on discussions with company leadership and perusal of the state's primary industry magazine.

Figure 7 illustrates a simplified overview of the investments and their implementers.

The wholesaler installed optical sorting systems, expanded storage capacity, and improved transportation logistics. These investments enhanced product quality through better sorting and more efficient, vertically coordinated delivery systems. As a result of OSS adoption, wholesalers began offering price premiums to growers for higher-quality potatoes, incentivizing them to invest in improved field practices and on-farm storage infrastructure.

Investments in OSS, storage, and transportation were critical for improving both product quality and sales volume. During the study period, the new local brand was the first, and for many years the only, wholesaler in Wisconsin to have adopted OSS technology. The Little Potato Company, which specializes in creamer potato varieties, established a local shipping and processing facility in Wisconsin that included an OSS in 2017[8][9]. The next local shipper-packer to invest in OSS was the Russet Potato Exchange in 2022. This unique technological position allows us to distinguish between wholesalers with and without OSS, enabling identification of the technology's impact on marginal costs for 2010-2017 period.

4.2 Commodity and Specialty Sales in Major Retailers

Figure 8 illustrates the sales trends for fresh potatoes in Wisconsin across different product types and retail chains, focusing on the new local brand and store-brand Russet potatoes in both traditional and modern retail chains. We distinguish between commodity varieties (e.g., Russet) and specialty varieties (e.g., premium or creamer types).

Sales of the new local brand in Wisconsin increased steadily across all product types, reaching a peak in 2013 within modern retail chains. These elevated sales levels remained stable in subsequent years. In contrast, traditional retailers experienced a significant decline in sales volumes in Wisconsin over the same period.

Additionally, beginning in 2014, we observe a notable increase in sales outside of

[8] https://www.midwestfarmreport.com/2017/07/27/little-potato-company-opens-new-processing-facility-in-deforest/

[9] https://www.potatogrower.com/2016/07/little-potato-company-builds-first

Wisconsin (Figure 9). The expansion of sales beyond the state suggests strong market performance and growing consumer acceptance of the new local brand regionally.

These patterns are consistent with the hypothesis that technology adoption—combined with vertical coordination through marketing contracts—enhances product quality, supply reliability, and ultimately market competitiveness.

4.3 Long-Term Marketing Contracts

In this section, we present evidence suggesting that a key milestone in the development of the new local brand in Wisconsin was the establishment of marketing contracts with the modern retail chain in 2013.

The first piece of evidence comes from an interview with the leadership of the new local brand, who stated that a 'close and productive relationship' with the retailer was made possible by the retailer's satisfaction with the consistent, high-quality supply they were able to provide, which was made possible by their adoption of an OSS and investments in storage and logistics.

The second piece of evidence highlights a common feature of marketing contracts: retail prices are linked to contract prices established through private negotiations between wholesalers and retailers, rather than being directly tied to fluctuations in open-market wholesale prices. To illustrate this, we analyze the price - volume dynamics of the most popular Russet potato products in the retail market. Figures 10a and 10b depict these dynamics in a densely populated market - Milwaukee. After September 2013, the in-store price of the new local brand stabilized and ceased to track the Wisconsin spot price. In contrast, the price of its largest competitor continued to closely follow spot market fluctuations.

Furthermore, the summary statistics in Table 1 show that the weighted standard deviation of in-store prices for the new local brand's Russet potatoes declined markedly -

from 0.10 to 0.05 -after the 2013 season. Meanwhile, price dispersion for traditional store brands remained relatively constant, averaging around 0.13. Over the same period, the market share of the new local brand nearly doubled, rising from 7% to 12.7%.

We interpret this reduction in price volatility, coupled with a substantial increase in market share, as empirical evidence of the stabilizing effect of long-term marketing contracts on consistent supply of new local brand products.

The last evidence supporting the shift to long-term marketing contracts and quality differentiation is the disappearance of Wisconsin-grown creamer potato varieties from AMS USDA shipping point reports for Central Wisconsin following the 2013 growing season (U.S. Department of Agriculture, Agricultural Marketing Service 2025a),(U.S. Department of Agriculture, Agricultural Marketing Service 2025c). Notably, this disappearance does not coincide with a decline in overall local volume of premium specialty varieties in the Wisconsin market. Instead, we interpret this as an indication that increased demand for higher-quality products led to a reallocation of these transactions into privately negotiated, long-term marketing contracts. As a result, such transactions no longer appear in publicly reported spot market data.

5 Empirical Framework

Our strategy involves estimating consumer demand to recover the price elasticities of products produced by wholesalers with and without quality enhanced technologies before and after a contractual change in Wisconsin fresh potato market. Using these demand estimates, we apply a Nash-Bertrand pricing model to infer the marginal costs of products. This approach allows us to compare the marginal costs of products sold in the modern retailer who signed contracts with the wholesaler that invested in product quality against those who did not. Through this comparison, we can identify and quantify the effects of wholesale investment on product quality as well as the impact of contractual changes on pricing and cost structures.

5.1 Demand

We rely on a discrete-choice framework in which consumer preferences are defined over product characteristics, incorporating heterogeneity through a random coefficients specification (Berry et al. 1993). The utility that consumer i derives from product j in market t is given by:

$$u_{ijt} = \delta_{jt} + \mu_{ijt} + \varepsilon_{ijt} \tag{1}$$

In this specification, δ_{jt} represents the mean utility of product j in market t, μ_{ijt} captures consumer-specific deviations from the mean utility, and ε_{ijt} is an i.i.d. extreme value error term.

Mean utility is modeled as:

$$\delta_{jt} = X_{jt}\beta - \alpha p_{jt} + \xi_{jt} \tag{2}$$

Here, X_{jt} denotes observed product characteristics, p_{jt} is the price, β and α are parameters to be estimated, and ξ_{jt} is an unobserved product-market shock.

The market share of product j in market t is given by:

$$s_{jt} = \int \frac{\exp(\delta_{jt} + \mu_{ijt})}{1 + \sum_{k=1}^{J} \exp(\delta_{kt} + \mu_{ikt})} dF(\nu_i) \tag{3}$$

5.2 Estimation Procedure

The estimation procedure follows a nested structure with outer and inner loops. In the outer loop, structural parameters $\theta = (\beta, \alpha)$ are estimated using the Generalized Method of Moments (GMM). The moment condition is:

$$E[Z_{jt} \cdot \xi_{jt}(\theta)] = 0 \tag{4}$$

The instrument set Z_{jt} includes differentiation instruments (Gandhi and Houde 2019), local supply indicators for russet, red A, and red B potatoes, season-month dummies to capture pre- and post-harvest effects, and product characteristics that proxy for cost-related attributes such as national branding, low-cost variants, and premium positioning. Further details on instrument construction and relevance are provided in the section 6.

In the inner loop, we invert observed market shares to recover the mean utility δ_{jt} using a contraction mapping procedure introduced by (Steven T. Berry and Pakes 1995):

$$\delta_{jt}^{(n+1)} = \delta_{jt}^{(n)} + \log(s_{jt}^{obs}) - \log(s_{jt}^{model}) \tag{5}$$

This iterative process continues until convergence, ensuring that the model-predicted market shares s_{jt}^{model} closely match the observed shares s_{jt}^{obs}.

5.3 Supply Side: Marginal Cost Specification

We model the marginal cost of product j, as a linear function of observed cost shifters w_j:

$$mc_j = w_j'\gamma + \omega_j \quad (6)$$

These cost shifters include input prices—specifically, the shipping point price used as a proxy for the wholesale price paid by retailers—and product characteristics that are closely related to production costs, such as bag size and product category. The vector γ contains parameters to be estimated, while ω_j captures unobserved cost shocks.

The moment condition in equation 7 assumes that the unobserved cost shock ω_j is mean-independent of the instruments Z_j, meaning that these instruments influence marginal cost but are uncorrelated with the error term:

$$E[\omega_j|Z_j] = 0 \quad (7)$$

In our setting, we use the shipping point price, and indicator variables for product category and bag size as instruments. The shipping point price serves as a proxy for the wholesale price paid by retailers, capturing variation in input costs across retailers and time. Product category indicators reflect systematic differences in production and handling costs between commodity and specialty varieties, while bag size indicators account for packaging-related cost differences (the smaller bags often relate to more premium products). These variables are plausibly exogenous to the unobserved cost shock ω_j, making them suitable instruments for identifying the marginal cost function.

Because the fresh potato industry is highly demand-driven, we suspect that the shipping point prices may be influenced by demand shocks. Additional anecdotal evidence supports this concern. Wholesalers without optical sorting systems have reported that retailers often stick to open market prices. As a result, wholesalers must decide whether or not to supply the specific product at this price, which differs notably from the negotiation process between the new local brand and modern retailer. To address this potential endogeneity, we implement two empirical specifications.

First, we estimate demand without relying on cost-side moments. In this specification, we use the following instruments: two differentiation IVs, three local supply indicators (russet, red A-size, red B-size), month indicators for periods before and after harvest, and indicators for product characteristics closely tied to cost—namely, national brand, budget product, and premium group. Due to numerical instability in highly volatile data, particularly for specialty varieties, we observe near-zero elasticities for some outliers (which comprised about 7% of the observations). These outliers significantly distort marginal cost estimates for specialty potatoes. Removing them gives results for major products similar to those obtained from the constrained estimation described below.

Second, we estimate a constrained model in which marginal cost is specified as a linear function and restricted to be non-zero but less than \$2—twice the average price of premium varieties in our sample. This constraint reflects realistic bounds for marginal cost in the fresh potato industry, where production and handling costs are relatively low but vary across product types and packaging formats.

5.4 Recovering Marginal Costs

We assume retailers engage in static Nash-Bertrand competition in prices. Each firm i chooses prices for its portfolio of products $j \in \mathscr{F}_i$ to maximize profits in each market (county-zip code-retailer) t, taking competitors' prices as given.

The firm's profit function is:

$$\Pi_i = \sum_{j \in \mathscr{F}_i} (p_{jt} - mc_{jt}) \cdot S_{jt}(p) \cdot M_t - C_i \tag{8}$$

In this expression, p_{jt} denotes the price of product j, mc_{jt} is the marginal cost, $S_{jt}(p)$ represents the market share as a function of prices, M_t is the market size, and C_i is the fixed cost for firm i.

The first-order condition (FOC) for profit maximization is:

$$S_{jt}(p) + \sum_{k \in \mathscr{F}_i} \frac{\partial S_{kt}(p)}{\partial p_{jt}} (p_{kt} - mc_{kt}) = 0 \tag{9}$$

To facilitate recovery of marginal costs, define the Jacobian matrix Δ of partial derivatives as:

$$\Delta_{jk} = \begin{cases} \frac{\partial S_{jt}}{\partial p_{kt}} & \text{if } j,k \in \mathscr{F}_i \\ 0 & \text{otherwise} \end{cases} \tag{10}$$

Using this matrix, marginal costs are recovered via the following inversion:

$$mc_t = p_t - \Delta^{-1} S_t \tag{11}$$

Here, p_t and S_t are vectors of prices and market shares for all products in market t. The derivatives $\frac{\partial S_{jt}}{\partial p_{kt}}$ are computed via simulation using the estimated demand parameters from the BLP model. This inversion procedure ensures consistency between observed pricing behavior and estimated demand elasticities.

5.5 Ownership Matrix

The recovery of marginal costs under Nash-Bertrand pricing critically depends on the assumed ownership structure of products. To construct the ownership matrix, we rely on institutional knowledge obtained through interviews with wholesalers and producers. This information allows us to identify which products are jointly priced by the same decision-making entity in each market. For example, we observe that the new local brand negotiates directly with modern retail chains. These negotiations typically involve a menu of prices and volumes across all products under the brand's portfolio. As such, we assume that this wholesaler maximizes profits jointly over its entire product line, and we assign common ownership across these products in the matrix. For example, we observe that the new local brand—operated by a wholesaler with advanced quality-sorting and packaging technology—negotiates directly with modern retail chains. These negotiations typically involve a menu of prices and volumes across all products under the brand's portfolio. As such, we assume that this wholesaler maximizes profits jointly over its entire product line, and we assign common ownership across these products in the matrix.

In contrast, private brand products sold by traditional retail chains follow a different procurement model. These retailers primarily source from the open market, especially for commodity varieties, and do not engage in long-term contracts or volume commitments, especially for commodity varieties. Their purchasing behavior may be opportunistic: they buy in larger quantities when prices are low and reduce purchases when prices rise. This leads to less efficient inventory management compared to modern retailers, who rely on marketing contracts with stable pricing and regular delivery schedules. As a result, traditional retailers may experience higher spoilage rates, particularly for perishable products like potatoes, which contribute to higher estimated marginal costs.

We tested the hypothesis that traditional retailers jointly optimize prices across all store-brand products using Nash-Bertrand framework. However, this assumption led to economically implausible results – the implied marginal costs were negative for over 50% of the observations. This result suggests that the joint optimization assumption for private brands does not hold in this context. As a result, we assume that private brand products are sourced from different wholesalers who work with different growers, each specializing in a particular variety (e.g., Russet, red A-size, red B-size). Accordingly, we assign separate ownership to each store-brand product by variety. Under this assumption, the retailer applies a fixed markup over the open-market purchase price for each variety and does not frequently adjust prices in response to cross-variety substitution patterns. This pricing behavior aligns with institutional realities in the fresh potato industry, where private label (store-brand) potatoes represent a relatively small share of total sales for traditional grocery chains and are not typically a strategic pricing priority.

Industry reports suggest that fresh potatoes are primarily valued for their role in driving basket size and overall store performance, rather than for their individual profit margins.[10] Retailers often focus their pricing and merchandising strategies on high-volume, branded, or value-added products, while private label items—especially in commodity categories like potatoes—are priced more rigidly and with less frequent adjustment. This strategy is consistent with anecdotal evidence from wholesalers, who report that retailers often provide fixed price menus for different potato varieties, which wholesalers must accept or reject, including the negotiation between the new local brand and the modern retailer.

[10] https://www.potatonewstoday.com/2025/06/10/at-the-heart-of-the-produce-aisle-how-potatoes-are-winning-at-retail-in-2025/

6 Identification

To address the endogeneity of prices in demand estimation, we employ a set of instrumental variables.

6.1 Differentiation IV

We construct two differentiation instruments: the number of close substitutes from the same brand and the number of close substitutes from competing brands(Petrin 2002; Conlon and Gortmaker 2020; Gandhi and Houde 2019). These instruments serve as proxies for retailers' markup-setting behavior, based on the assumption that products facing more close substitutes experience greater competitive pressure and thus lower markups. The validity of these instruments depends on the condition that product proliferation does not outpace market expansion. When the number of products grows disproportionately faster than the number of markets, the correlation between BLP-style instruments and markups weakens, reducing their effectiveness (Armstrong 2016).

This concern motivates our decision to restrict the sample to periods prior to 2017. In that year, the Canadian brand *Little Potato Company* entered the U.S. market and established packing and cleaning facilities for creamer potato varieties. This entry led to a sharp increase in product variety—approximately 100 new UPCs—undermining the validity of the Differentiation IVs by diluting the competitive signal they are intended to capture.

We construct these instruments using the full RMS panel for the three largest retail chains in Wisconsin. To ensure robustness, we exclude products with negligible market shares (less than 0.1% of total volume) and those priced above \$2—twice the sample average. These exclusions, which together account for less than 2.7% of total volume, prevent the standard deviation of price from being inflated by outliers. Without these exclusions, the price bandwidth would become overly broad, rendering all products as close substitutes and invalidating the instrument.

The price standard deviation is computed at the season-chain-county-ZIP code. Within this bandwidth, we count the number of products from the same brand and from other brands to form the two Differentiation IVs. These instruments exhibit strong variation for commodity varieties (e.g., Russets) and specialty varieties (e.g., red A-size potatoes), but are less informative for niche segments such as premium and budget products, where within-group variation is limited.

Differentiation IVs capture a product's relative position on the quality ladder by quantifying the degree of competitive pressure it faces from nearby substitutes (Gandhi and Houde 2019). Specifically, for each product in each market, we construct instruments that reflect the number of close substitutes within a price bandwidth defined by the standard deviation of prices, weighted by sales volume (in pounds). In the fresh potato market, there is a clear segmentation between commodity and specialty products (Figure 11).

6.2 Local Supply Instrument

To further address potential endogeneity in pricing, we construct a supply-side instrument that captures exogenous variation in transportation and procurement costs arising from geographic sourcing constraints. This instrument serves as a proxy for cost shocks that influence wholesale and retail prices but are plausibly uncorrelated with unobserved demand shocks.

For national-brand products—particularly Russet varieties—the instrument reflects the cost implications of transporting potatoes from Idaho, the primary production region, to retail markets in Wisconsin.

For red potato varieties, the instrument captures seasonal periods of limited local supply in Wisconsin, typically spanning February through July. During these months, wholesalers and retailers are more likely to source from out-of-state suppliers, incurring higher procurement and logistics costs. We identify these off-season periods using USDA AMS data by tracking the absence of open market transactions for fresh red potatoes in Wisconsin. The absence of reported transactions serves as a proxy for the unavailability of local supply.

We construct a binary indicator variable that equals one during months when local supply is available, reflecting the increased likelihood of reliance on nearby sources. This seasonal supply constraint introduces predictable variation in input costs that is orthogonal to local demand conditions and thus serves as a valid instrument for price.

7 Results

In this section, we present results from various demand model specifications. We then derive and discuss product-level elasticities and estimated marginal costs, and then assess the effects of the wholesaler investing in an optical sorting system and establishment of long-term marketing contracts between the wholesaler selling the new local brand and a modern retailer.

7.1 Demand Model Results

Table 2 reports the results from four demand model specifications. All models include a consistent set of product category controls, constructed from interactions between retailer chain dummies, variety dummies, national and generic brand indicators, and a new local brand indicator. Additionally, each specification controls for county fixed effects and season-month fixed effects.

Column I presents the results from a random coefficients logit model (BLP), which incorporates heterogeneous consumer preferences. This specification also incorporates a linear marginal cost function, which we adopt as our preferred model. The cost function includes several indicators variables that capture factors influencing marginal costs.

An indicator variable for **Shipped Locally** captures transportation cost advantages when products are sourced from nearby growers. The **Optical Sorting System** dummy identifies products supplied by wholesalers who have invested in quality-enhancing technologies, including the new local brand. **Bag size** indicators serve as proxies for differences in packaging and shipping costs (not shown in the table for brevity). Finally, the **Shipping Point Price** (SPP) is included as a proxy for wholesale and spot market prices across different varieties and wholesalers.

As previously noted, SPP is a rough approximation of wholesale pricing, particularly for specialty varieties. Due to the limited number of growers and the importance of sophisticated practices, prices for specialty products—especially bagged varieties—are often negotiated directly between wholesalers and retailers. While SPP may be endogenous to demand shocks due to retailer bargaining power, excluding it from the cost specification yields qualitatively similar results, suggesting robustness.

For robustness, Column I-A presents results from an unconstrained version of the BLP model. While the unconstrained specification generally performs well, it yields economically implausible own-price elasticity estimates—near-zero or negative—for approximately 7% of observations. These anomalies are most prevalent for premium specialty varieties, particularly red B-size potatoes, during periods of non-local supply when wholesalers must source from out-of-state. Under a Nash-Bertrand pricing framework, such elasticity estimates lead to unrealistically large price-cost margins. After excluding problematic observations, the own-price elasticities for most groups align closely with those in Column I, except for red B-size.

Columns II and III report results from standard logit and instrumental variable logit models. Compared to the more flexible BLP specifications, these models yield lower estimated price elasticities and produce counterintuitive predictions. Notably, they suggest that red B-size potatoes—a premium product—exhibit significantly higher price elasticity than Russet potatoes, which are typically treated as a commodity. This inconsistency undermines the models' ability to generate economically plausible price-cost margins, which are essential for accurate demand estimation across all potato varieties.

7.2 Discussion: Effects of Quality Enhancing Investments

According to Model I, demand for bagged potatoes is highly elastic, with an average price coefficient of approximately -14. The model also reveals substantial and economically plausible heterogeneity in price elasticities across varieties—more premium products tend to be more price inelastic.

We estimate the marginal cost specification using equations 7 and 4, and the results are reported in Table 3. The coefficient on the **Shipping Point Price** is 0.74, indicating strong pass-through from wholesale costs to retail prices. Sourcing potatoes locally is associated with a cost advantage of approximately 5.4 cents per pound, reflecting the savings in transportation costs compared to out-of-state sourcing.

The coefficient on the **Optical Sorting System** suggests that wholesalers who invest in quality-enhancing technologies—such as those used by the new local brand—benefit from a reduction in marginal costs of approximately 4.6 cents per pound.

This estimated cost advantage is economically meaningful. It likely reflects not only technological improvements but also operational efficiencies, such as better inventory management and reduced spoilage. These gains are further supported by stable marketing contracts between wholesalers and retailers, which enhance supply chain coordination and reduce uncertainty.

7.3 Contractual Change Effects on Brand Loyalty

This section examines changes in price elasticity following the 2013 season, when a new local brand switched from short-term to long-term marketing contracts with a modern retail chain. Our estimates suggest that this vertical coordination significantly influenced consumer price sensitivity.

Specifically, the own-price elasticity for Russet potatoes associated with the new local brand decreased in magnitude from -3.7 to -3.2, and for premium varieties from -3.3 to -2.97 (see Table 4).These changes coincide with price stabilization and increased market share (see Table 1), indicating a strengthening of brand loyalty as consumers became less responsive to price changes.

In contrast, the price elasticities for private label products remained largely unchanged after 2013 and continued to exhibit greater price sensitivity than the new local brand.

This is consistent with the fact that private label potatoes are typically sourced through the open market, without the benefits of long-term supply contracts or quality-enhancing investments.

The observed reduction in price elasticity for the local brand post-2013 aligns with higher estimated markups relative to traditional retailers. These retailers often lack formal supply agreements, and their wholesalers are less likely to invest in technologies such as optical sorting systems. Overall, the elasticity estimates suggest that the benefits of vertical coordination and marketing contracts—through improved supply chain stability and product quality—are economically meaningful. We explore these implications further in the following sections.

7.4 New Technology and Profitability

Figure 12 presents smoothed annual estimates of price-cost margins (in cents per pound), for Russet varieties across new local and private brands. The results indicate that the new local brand consistently earns higher margins—exceeding its counterparts by 3 to 5 cents—and shows a steady upward trend from 2011 to 2016.

The decline observed in 2016 may be partially attributed to the entry of the Canadian company *The Little Potato Company*, which established a 133,000-square-foot processing facility in DeForest, Wisconsin[11]. This marked the company's first U.S. operation and was part of a strategic expansion to meet growing demand for its proprietary Creamer potato varieties. As part of this initiative, the company expanded its contracted acreage with Wisconsin farmers from 400 to 4,000 acres for the 2016 growing season. These developments likely disrupted local market dynamics by introducing a well-capitalized competitor with modern processing capabilities and long-term agreements with local growers[12].

[11] https://www.midwestfarmreport.com/2017/07/27/little-potato-company-opens-new-processing-facility-in-deforest/

[12] https://www.wisfarmer.com/story/life/wis-farmer/2016/07/05/little-potato-company-builds-in-wisconsin/87343618/

7.5 Effect of OSS and Marketing Contracts for Commodity

We estimate the impact of the optical sorting system (OSS) and the marketing contract change introduced in September 2013 using a logic of ”difference-in-differences” regression framework. The analysis is restricted to Russet varieties, as the specialty varieties were already subject to contractual arrangements prior to the policy change. The regression specification is as follows:

$$\text{PCM}_{it} = \alpha + \beta_1 D_i + \beta_2 \text{Post}_t + \beta_3 (D_i \times \text{Post}_t) + \gamma X_{it} + \varepsilon_{it} \tag{12}$$

In this equation, PCM_{it} denotes the price-cost margin per pound for product i at time t, measured in cents. The variable D_i is is an indicator that the product is produced with an OSS to capture the general effect of OSS. The variable Post_t is an indicator for observations after September 2013. The interaction term $D_i \times \text{Post}_t$ captures the effect of the contract change specific to quality-enhanced products.

The vector X_{it} includes control variables such as interactions between retailer chains and time. The error term is represented by ε_{it}. The coefficient β_3 identifies the causal effect of the contract change on the margins of OSS-produced products after 2013.

The results in Table!6 indicate that the effect of quality-enhanced investments is approximately 4.71 cents per pound, which closely aligns with the gamma estimates reported in Table 3. The effect of the marketing contract change is estimated at 1.51 cents per pound.

These findings suggest that vertical coordination between technologically advanced wholesalers and modern retailers improves market efficiency. The cost savings likely reflect enhanced production and supply chain practices enabled by OSS technology and contractual arrangements. Moreover, the observed price reductions imply that some of these efficiency gains are passed on to consumers (see Table 1).

It is important to note that the estimated effects may be somewhat overstated, as they also capture complementary improvements such as better storage practices and reduced spoilage. These factors, while beneficial, are not separately identified in the current specification and may inflate the measured impact of OSS and contracts alone.

Overall, the results support the hypothesis that the combination of technology adoption and contractual coordination enhances market performance by reducing inefficiencies and aligning incentives across the supply chain.

8 Conclusion

This paper provides empirical evidence on how relational and formal marketing contracts facilitate vertical coordination and technology adoption in agricultural supply chains. Relational contracts play a foundational role by enabling initial trial investments, allowing stakeholders to assess the potential surplus generated through coordination. Once uncertainty is resolved and benefits are realized, formal long-term contracts are established to sustain and scale these gains.

Drawing on a detailed case study of the Wisconsin fresh potato industry, we show that the combination of quality-enhancing investments—particularly in Optical Sorting Systems (OSS)—and long-term marketing agreements between wholesalers and retailers leads to meaningful improvements in market performance. These include reduced marginal costs, increased price stability, and enhanced brand loyalty, contributing to more efficient and resilient supply chains.

Our findings indicate that OSS adoption is associated with a 4.71 cent per pound increase in price-cost margins, while marketing contracts contribute an additional 1.5 cent per pound. These effects reflect not only technological upgrades but also complementary improvements in logistics, storage, and inventory management, which reduce spoilage and improve supply reliability.

Importantly, these gains are reflected in observable market dynamics. The new local brand studied successfully differentiated itself from traditional store brands, expanded its market share, and extended its geographic reach. Post-contract, consumers exhibited reduced price sensitivity toward the local brand, suggesting stronger brand loyalty and perceived quality improvements. While the estimated effects may capture broader supply chain efficiencies beyond technology adoption alone, the results underscore the importance of aligning incentives across the supply chain. Both trust-based relationships and formal agreements play a critical role—especially in sectors where quality is difficult to monitor and investment incentives are misaligned.

However, it is important to acknowledge that environments characterized by strong relational ties and trust among stakeholders may also carry risks. Such settings can foster collusive behavior, where firms coordinate not only to improve efficiency but also to restrict competition, raise prices, or exclude rivals. These outcomes can be detrimental to consumers and broader market welfare. In particular, long-term contracts and close relationships may reduce transparency, limit entry, and weaken competitive discipline—especially in markets with few players and limited oversight. Therefore, while vertical coordination and trust-based contracting can yield substantial efficiency gains, they must be carefully monitored to ensure they do not undermine market competitiveness. Future research should explore the conditions under which relational contracting transitions from being efficiency-enhancing to anti-competitive, and how policy frameworks can balance these trade-offs.

Overall, this study advances the literature on supply chain modernization by providing rare empirical evidence from a developed-country agricultural sector. Focusing on the Wisconsin fresh potato industry, we show that investments in quality-enhancing technologies—most notably optical sorting systems—combined with the introduction of long-term marketing contracts, jointly improved efficiency, raised margins, and reduced spoilage. These results underscore how technological adoption and contractual coordination are complementary mechanisms for aligning incentives in vertically fragmented, quality-sensitive markets.

By situating our findings within broader patterns of U.S. agricultural modernization, we highlight that contracts are not only governance tools but also strategic vehicles for enabling and sustaining technology adoption. The Wisconsin case illustrates how relational foundations and formal agreements can work together to overcome hold-up problems, support quality upgrading, and strengthen brand positioning in perishable commodities. At the same time, it is important to acknowledge the potential trade-offs inherent in close coordination, including possible risks for competition. Incorporating these concerns into future research will be essential for fully understanding how contracts and technology jointly shape the trajectory of agricultural supply chains and brand development.

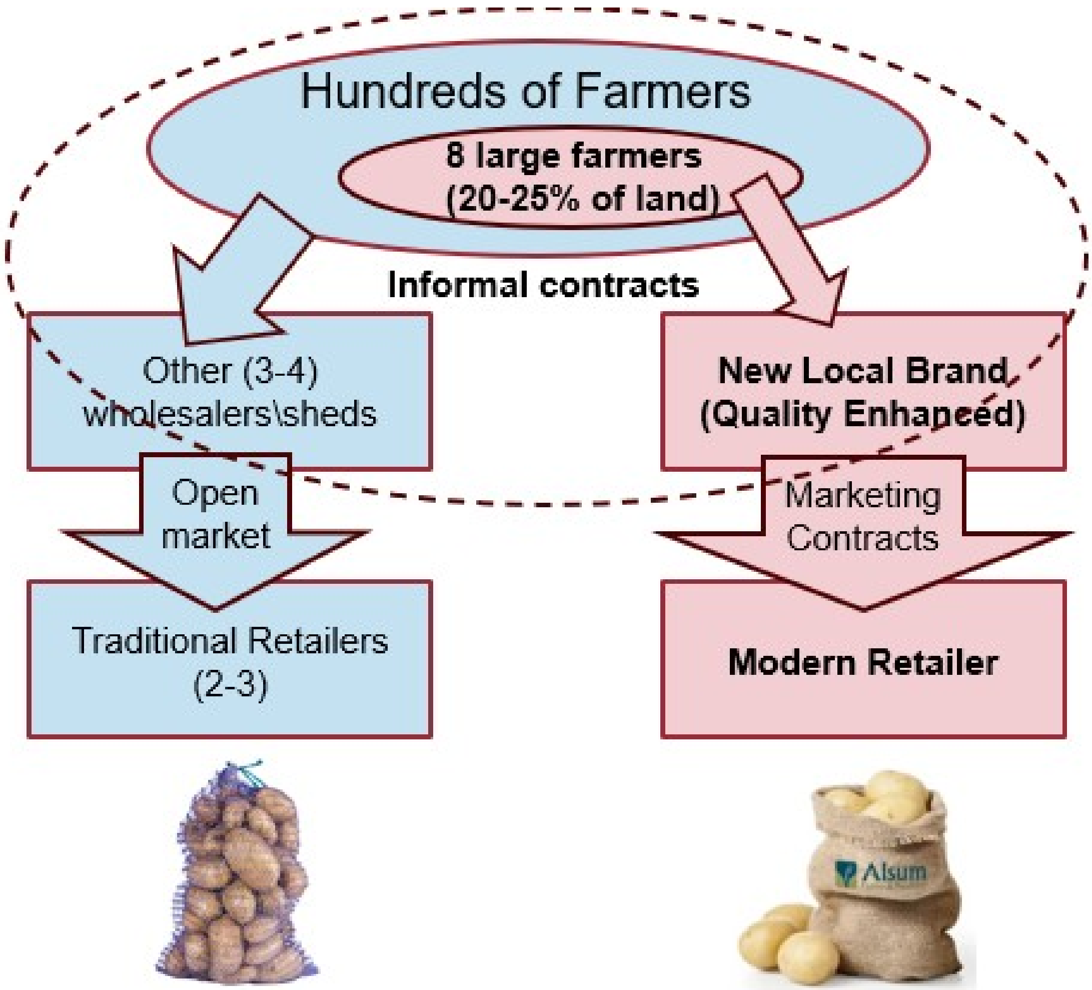


Figure 1: Market Structure in Wisconsin Fresh Potato

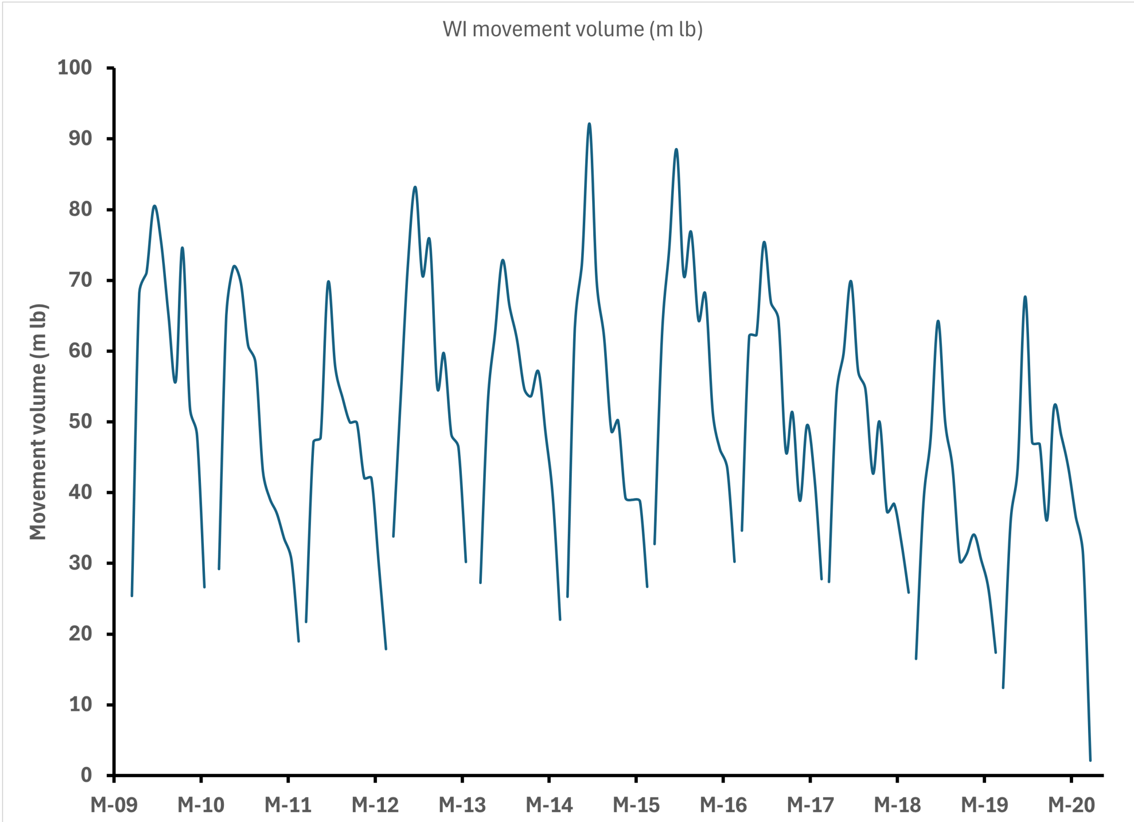


Figure 2: Russet movement data in Wisconsin, AMS USDA

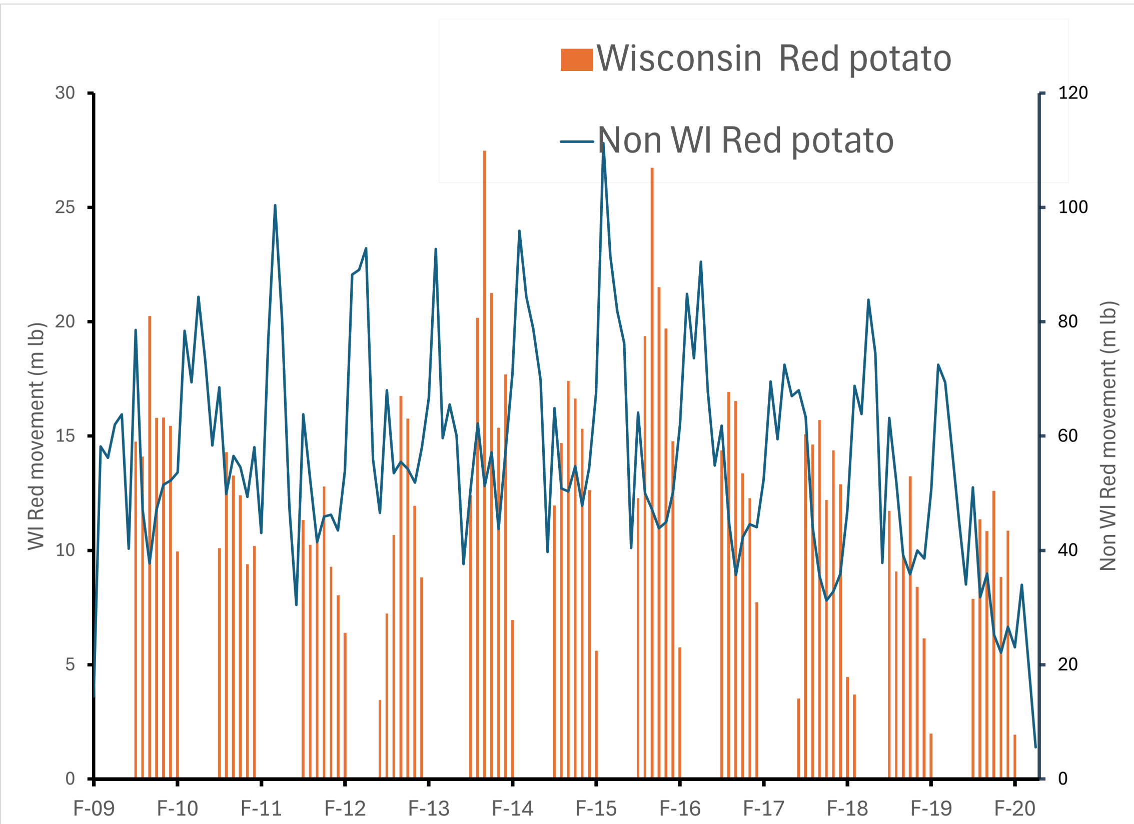


Figure 3: Red movement data, AMS USDA

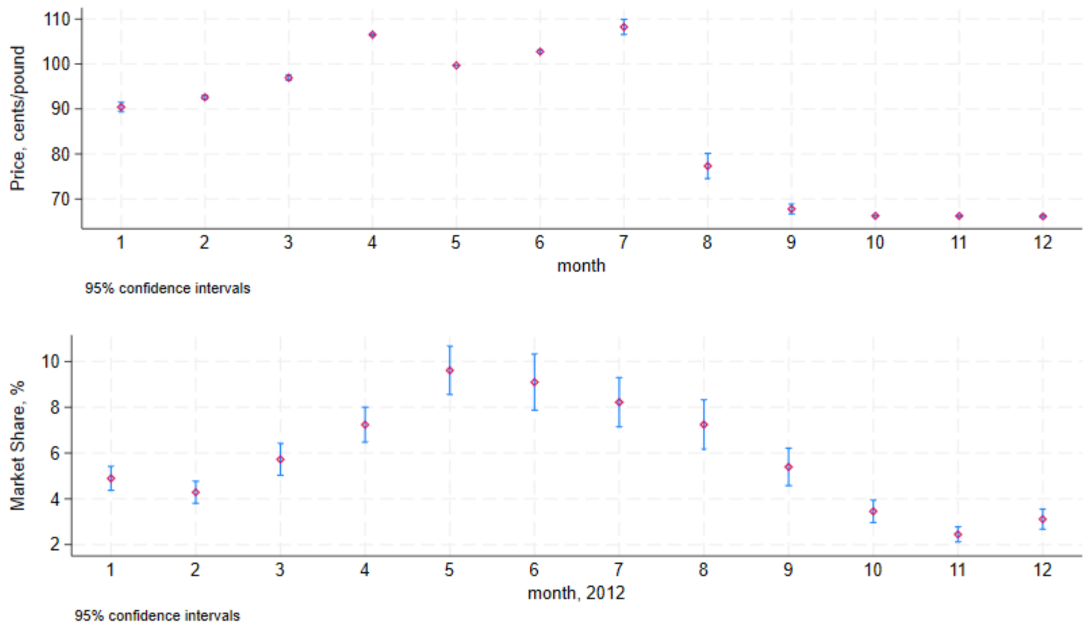


Figure 4: Retail price and volume for new local brand red B-size in Wisconsin

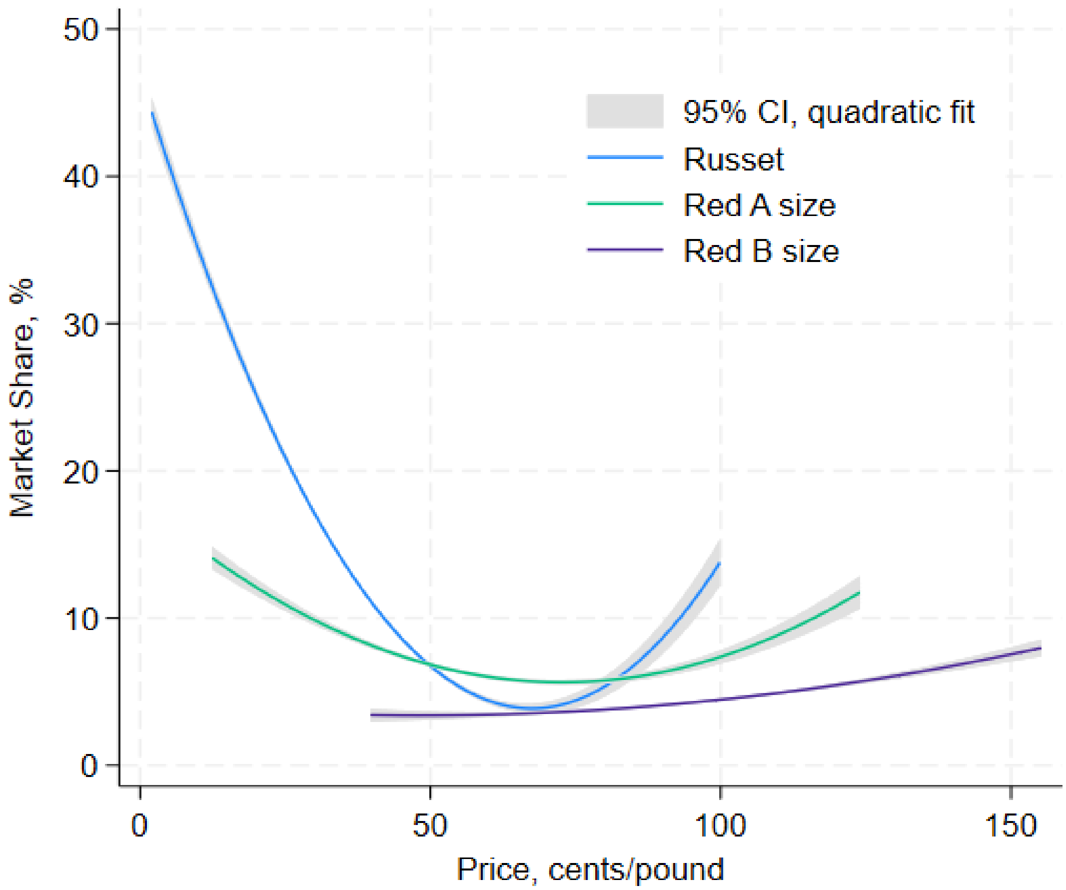


Figure 5: Price elasticity for potato varieties in Wisconsin in three largest retail chains (authors' estimates using Nielsen RMS)

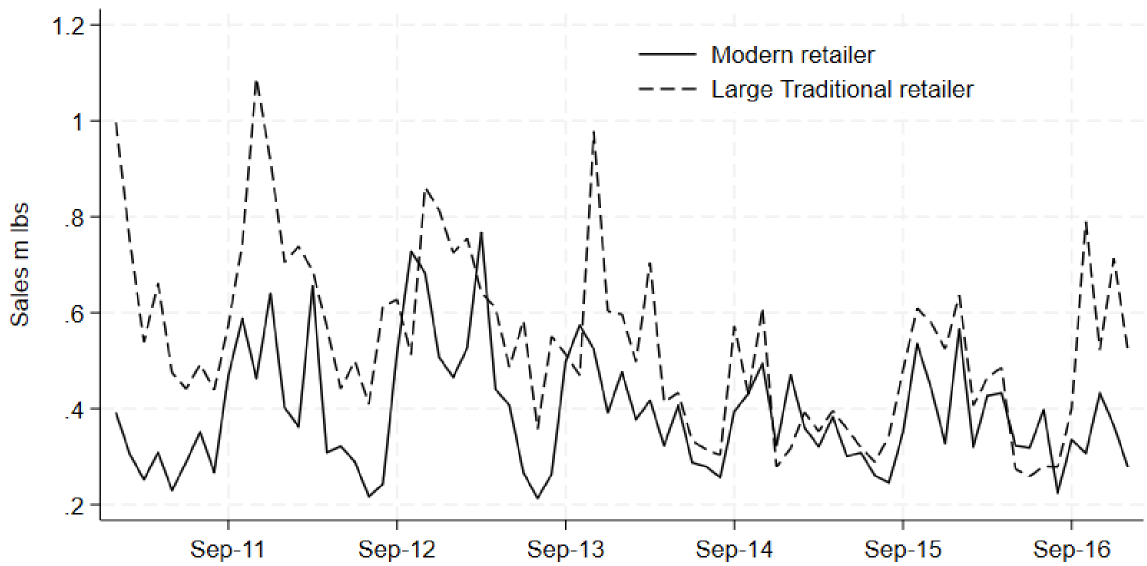


Figure 6: Russet potato sales in the largest retail chains in Wisconsin

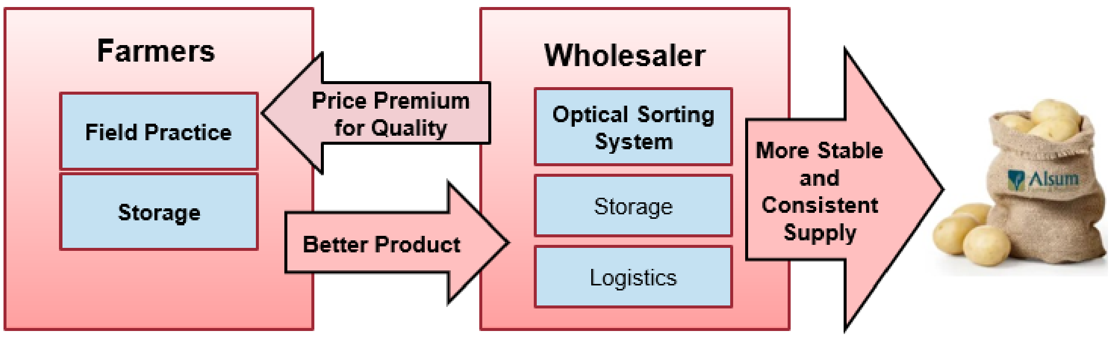
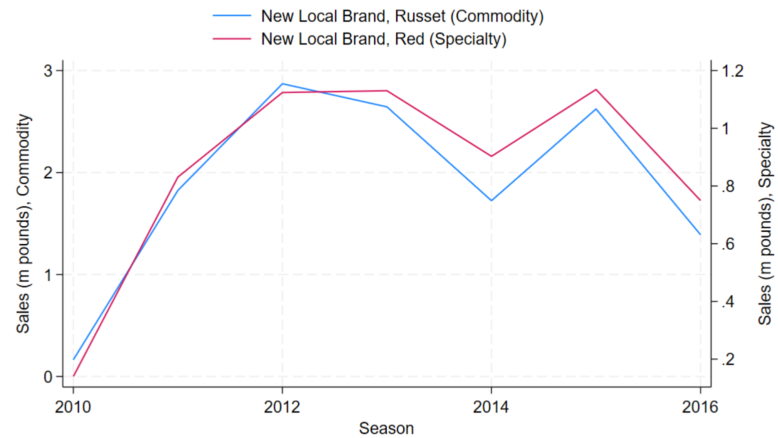
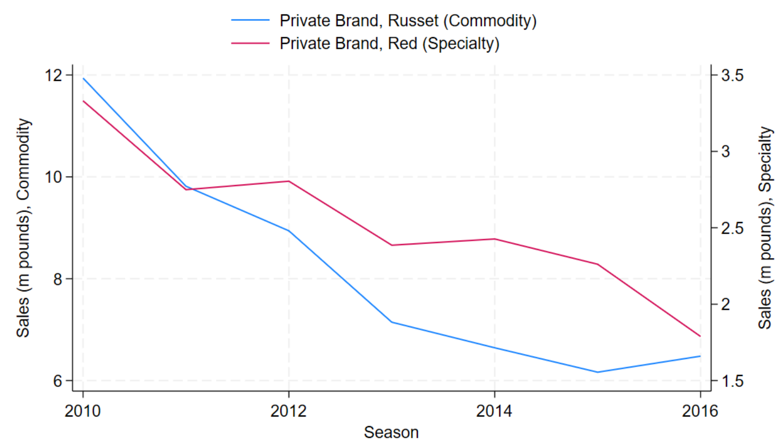


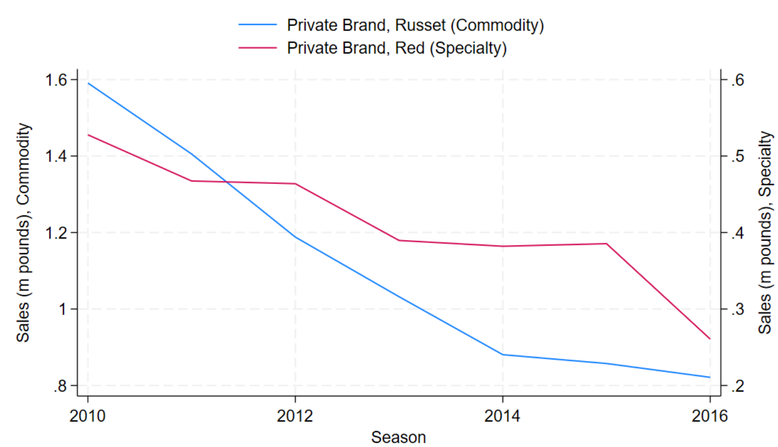
Figure 7: New local brand key investments



(a) New Local Brand (modern retailer)



(b) Private Brand (large traditional retailer)



(c) Private Brand (small traditional retailer)

Figure 8: Total Sales by variety (Source: Nielsen RMS data)

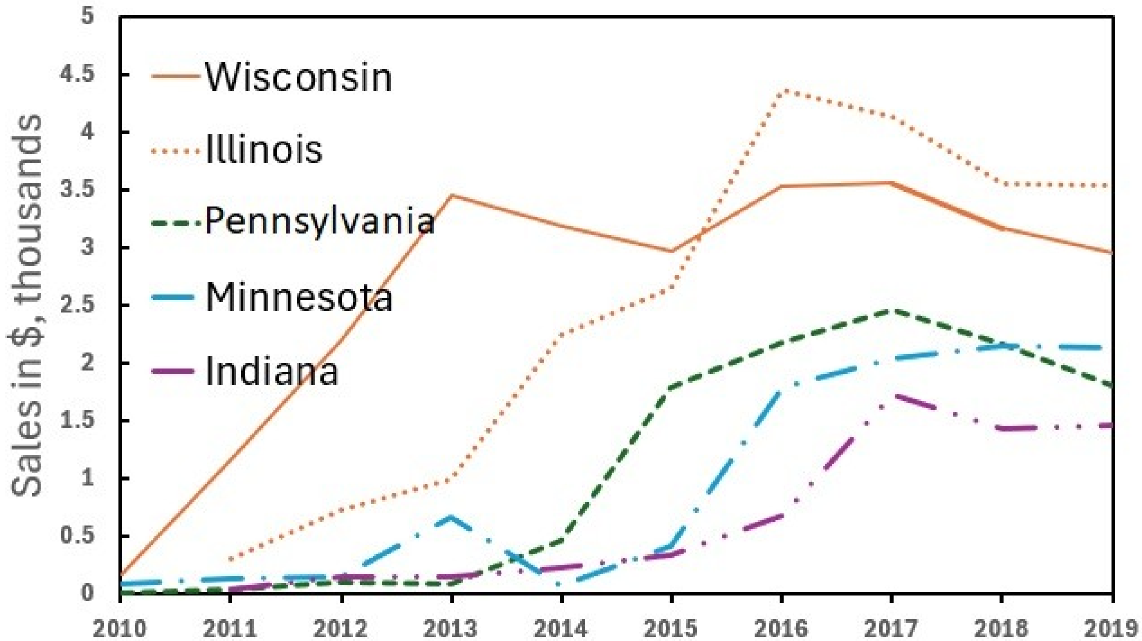
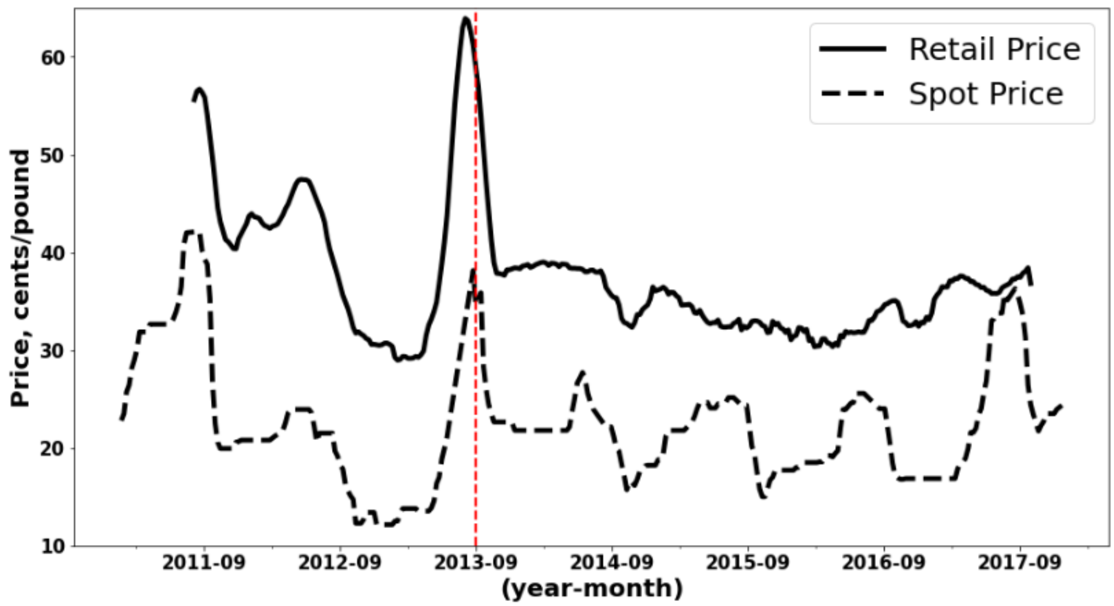
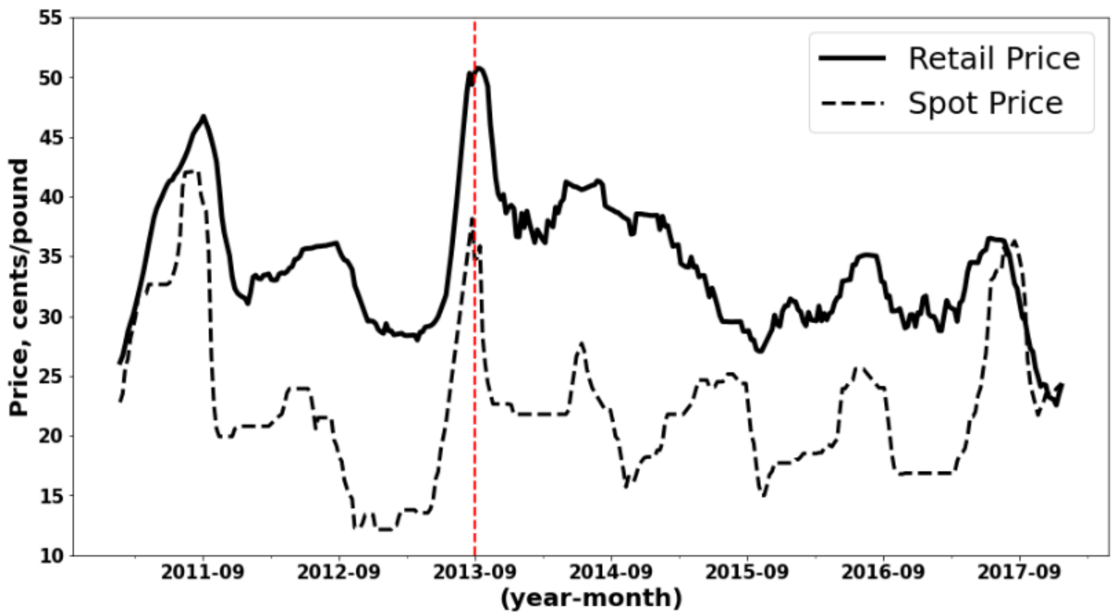


Figure 9: Geographic expansion of the new local brand (source: HMS)



(a) New Local brand (10 lb, modern retailer)



(b) Private Brand (10 lb, large traditional retailer)

Figure 10: Retail vs. Spot Price movements by russet brand in Milwaukee, WI

Red line represents the start of long-term marketing contracts between new local brand and modern retailer

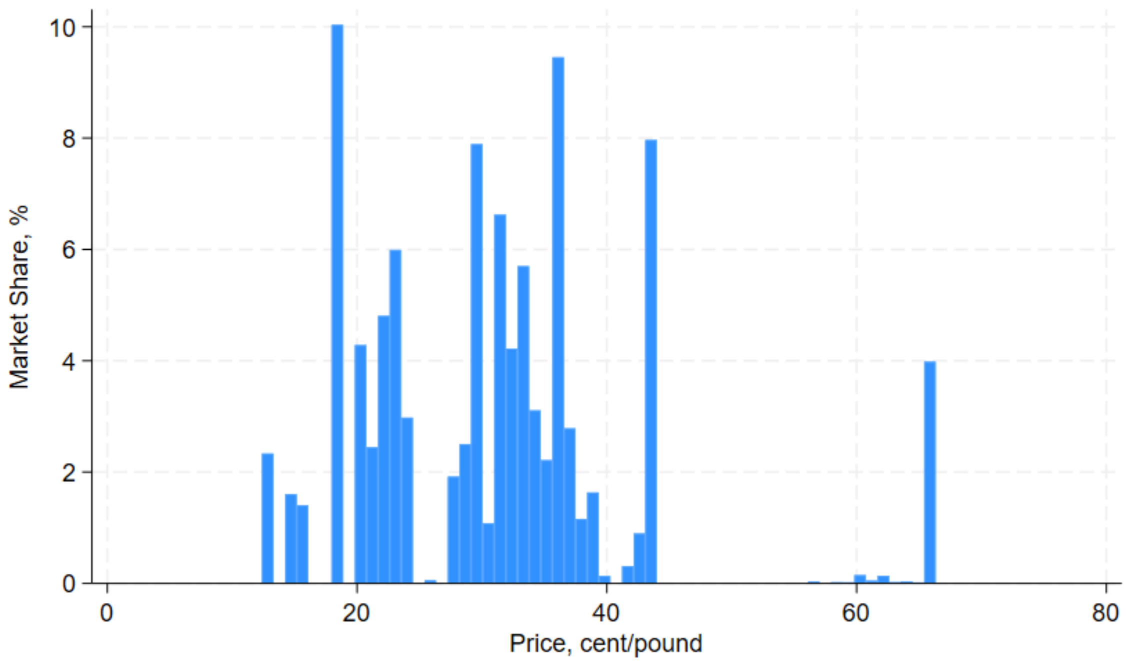


Figure 11: Market Shares by Price in a particular market

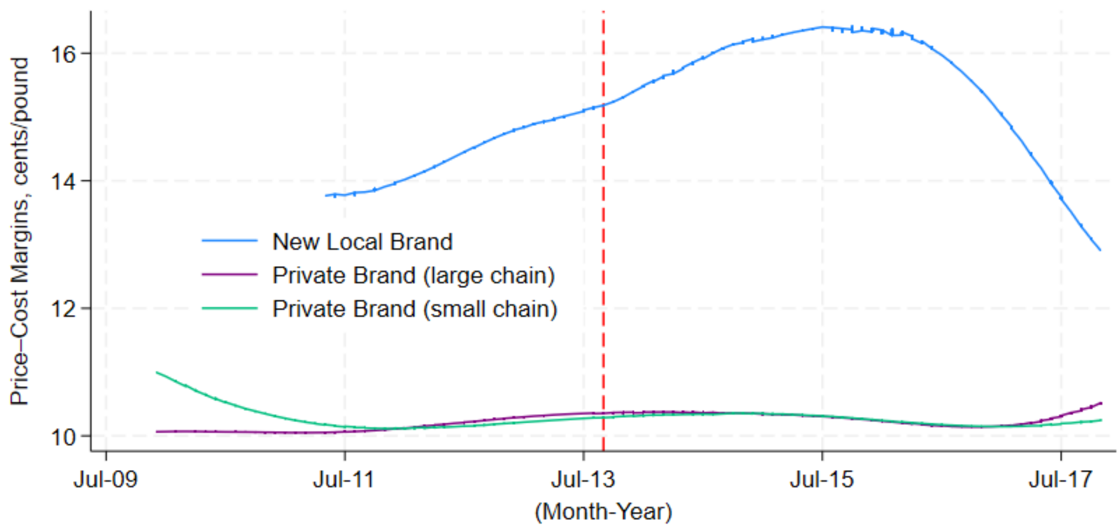


Figure 12: Average Russet Profits in cent per pound by Brand in Wisconsin

Table 1: Summary statistics before and after contractual change in Sep-13

Brand Type	Price, cents (Before / After)	Std Dev, cents (Before / After)	Market Share, % (Before / After)
Russet			
New Local	36 / 31	10.7 / 5.3	7.09 / 12.73
Store Large	37 / 36	13.4 / 13.0	46.77 / 45.29
Store Small	36 / 37	13.5 / 12.3	6.47 / 6.18
National	45 / 41	8.2 / 2.3	7.08 / 8.03
Red A size			
New Local	62 / 55	21.5 / 13.5	2.13 / 4.04
Store Large	59 / 53	12.4 / 8.7	8.37 / 9.62
Store Small	60 / 51	12.5 / 8.2	1.28 / 1.50
Red B size			
New Local	101 / 93	20.0 / 15.0	1.23 / 2.20
Store Large	94 / 86	13.4 / 14.3	3.29 / 3.50
Store Small	92 / 90	15.0 / 13.9	0.57 / 0.48

Note: Prices and price standard deviations are weighted by sales volume (in lbs).

Table 2: Demand Parameter Estimation*

	BLP (with supply side) (I)	**BLP**** (I-A)	**Logit (IV)** (II)	**Logit** (III)
Price	-14.10	-14.62	-4.84	-2.67
	(0.44)	(0.68)	(0.170)	(0.052)
Own Price Elasticities				
Russet	-3.69	-4.17	-1.88	-1.05
Red A size	-4.66	-4.61	-2.63	-1.47
Red B size	-3.36	-1.93	-4.16	-2.32
Instrumental variables	Yes	Yes	Yes	No
Observations	39,731	39,731	39,731	39,731

Elasticities are computed across all products, including generics and small brands.
* Elasticities computed across all products, including generics and small brands.
**Elasticities computed after excluding 7% of observations with near-zero own price elasticities (outliers).

Table 3: Gamma Estimates for Marginal Cost Specification

Variable	Shipped Locally	Optical Sorting System	Shipping Point Price
Gamma Estimate	-0.053	-0.046	0.736
Standard Error	(0.002)	(0.004)	(0.027)

Table 4: Elasticity Response to 2013 Contract Change

Brand Type	**Own Elasticity** Before	**Own Elasticity** After	**Cross Elasticity*** Before	**Cross Elasticity*** After
Russet				
New Local Brand	-3.70	-3.24	0.34	0.33
Private Large Brand	-3.55	-3.47	0.38	0.38
Private Small Brand	-3.49	-3.39	0.44	0.40
National Brand	-4.53	-4.06	0.40	0.37
Red A size				
New Local Brand	-5.00	-4.58	0.37	0.36
Private Large Brand	-4.93	-4.59	0.40	0.40
Private Small Brand	-4.88	-4.55	0.48	0.44
Red B size				
New Local Brand	-3.33	-2.97	0.18	0.17
Private Large Brand	-3.51	-3.43	0.23	0.24
Private Small Brand	-3.55	-3.07	0.29	0.22

**Cross elasticities are estimated after aggregating across all other products, including those from the same brand.*

Table 5: Markup and Marginal Cost per pound Before and After 2013 Contract Change

Brand Type	**Markup (%)** Before	**Markup (%)** After	**Marginal Cost (¢)** Before	**Marginal Cost (¢)** After
Russet				
New Local	48.4	53.0	19.9	15.4
Store Large	33.2	33.4	25.0	24.1
Store Small	33.6	33.4	24.3	23.7
National	26.9	27.7	33.2	30.0
Red A size				
New Local	37.8	41.1	39.5	34.5
Store Large	22.2	23.2	48.4	44.0
Store Small	22.3	23.6	48.9	41.9
Red B size				
New Local	42.8	48.2	58.2	49.5
Store Large	31.6	32.8	64.3	58.3
Store Small	31.1	36.6	63.0	57.3

Table 6: Effect of OSS and Contract Change on Russet Price-Cost Margin

Dependent Variable: PCM (cents)	Coefficient	Std. Error	t-stat	p-value
Local Brand (OSS)	4.713	0.119	39.46	0.000
Post-2013	-0.964	0.261	-3.69	0.000
Local Brand × Post-2013	1.511	0.137	11.02	0.000
Observations		24,846		
R-squared		0.55		

Notes: The dependent variable is price-cost margin (PCM), measured in cents per pound.

References

Abel, Andrew B. (1983). "Optimal Investment under Uncertainty". In: *American Economic Review* 73.1, pp. 228–233. URL: https://www.jstor.org/stable/1803942.

Armstrong, Timothy B. (2016). "Large market asymptotics for differentiated product demand estimators with economic models of supply". In: *Econometrica* 84.5, pp. 1961–1980. URL: https://doi.org/10.3982/ECTA10600.

Asirvatham, Jebaraj and Bhuyan, Sanjib (2018). "Incentives and Impacts of Vertical Coordination in a Food Production-Marketing Chain: A Non-cooperative Multi-Stage, Multi-Player Analysis". In: *Journal of Industry, Competition and Trade* 18, pp. 59–95. DOI: 10.1007/s10842-017-0247-2. URL: https://doi.org/10.1007/s10842-017-0247-2.

Baker, George, Gibbons, Robert, and Murphy, Kevin J. (2001). "Bringing the market inside the firm?" In: *American Economic Review* 91.2, pp. 212–218. URL: https://doi.org/10.1257/aer.91.2.212.

— (2002). "Relational contracts and the theory of the firm". In: *The Quarterly Journal of Economics* 117.1, pp. 39–84. URL: https://doi.org/10.1162/003355302753399445.

Berry, Steven T., Levinsohn, James A., and Pakes, Ariel (1993). *Automobile prices in market equilibrium: Part I and II*. URL: https://www.nber.org/papers/w4264.

Bloom, Nicholas, Bond, Stephen, and Reenen, John Van (2007). "Uncertainty and Investment Dynamics". In: *Review of Economic Studies* 74.2, pp. 391–415. DOI: 10.1111/j.1467-937X.2007.00426.x. URL: https://academic.oup.com/restud/article/74/2/391/1584277.

Calvin, Linda (2004). "Food safety in food security and food trade: Case study on the US produce industry". In: *International Food Policy Research Institute Brief* 10. URL: https://www.fooddiagnostics.dk/wp-content/uploads/Food_Safety_in_Food_Security_and_Food_Trade.pdf.

Caputo, Vincenzo and Reardon, Thomas (2025). “Hiding and revealing: a perspective on the paradox of information transparency in diverse agri-food value chain contexts”. In: *Q Open* 5.2. DOI: 10.1093/qopen/qoaf017. URL: https://doi.org/10.1093/qopen/qoaf017.

Chernev, Alexander and Hamilton, Ryan (2009). “Assortment Size and Option Attractiveness in Consumer Choice Among Retailers”. In: *Journal of Marketing Research* 46.3, pp. 410–420. DOI: 10.1509/jmkr.46.3.410. URL: https://www.kellogg.northwestern.edu/~/media/Files/Faculty/Research/Assortment_Size_Consumer_Choice_Among_Assortments_JMR_200910.ashx.

Coase, Ronald H. (1993). “The nature of the firm (1937)”. In: *Economica* 4, pp. 396–405. URL: https://www.jstor.org/stable/2626876.

Conlon, Christopher T. and Gortmaker, Jeff (2020). “Best Practices for Demand Estimation with PyBLP”. In: *RAND Journal of Economics* 51.4, pp. 1108–1162. DOI: 10.1111/1756-2171.12331.

Crosby, T.W. and Wang, Y. (2021). “Effects of different irrigation management practices on potato (Solanum tuberosum L.)” In: *Sustainability* 13, p. 10187. URL: https://doi.org/10.3390/su131810187.

Essien, Emmanuel, Zhang, Yifan, Kumar, Sameer, and Singh, Rajesh (2023). “Unveiling the factors influencing transparency and traceability in agri-food supply chains: an interconnected framework”. In: *Supply Chain Management* 29.3. DOI: 10.1108/scm-02-2023-0083. URL: https://doi.org/10.1108/scm-02-2023-0083.

Gandhi, Amit and Houde, Jean-François (2019). “Measuring substitution patterns in differentiated-products industries”. In: *NBER Working Paper* w26375. URL: https://www.nber.org/papers/w26375.

Ge, Deng, Pan, Yi, Shen, Zuo-Jun, Wu, Di, Yuan, Rong, and Zhang, Chao (2019). “Retail supply chain management: a review of theories and practices”. In: *Journal of Data,* *Information and Management* 1, pp. 45–64. DOI: 10.1007/s42488-019-00004-z. URL: https://link.springer.com/article/10.1007/s42488-019-00004-z.

Gibbons, Robert (2005). "Four formal (izable) theories of the firm?" In: *Journal of Economic Behavior & Organization* 58.2, pp. 200–245. URL: https://doi.org/10.1016/j.jebo.2004.09.010.

Grossman, Sanford J. and Hart, Oliver D. (1986). "The costs and benefits of ownership: A theory of vertical and lateral integration". In: *Journal of Political Economy* 94.4, pp. 691–719. URL: https://doi.org/10.1086/261404.

Hansman, Christopher, Hjort, Jonas, León-Ciliotta, Gianmarco, and Teachout, Matthieu (2020). "Vertical integration, supplier behavior, and quality upgrading among exporters". In: *Journal of Political Economy* 128.9, pp. 3570–3625. URL: https://doi.org/10.1086/708817.

Hart, Oliver and Moore, John (1990). "Property rights and the nature of the firm". In: *Journal of Political Economy* 98.6, pp. 1119–1158. URL: https://doi.org/10.1086/261729.

Holmstrom, Bengt and Milgrom, Paul (1991). "Multitask principal–agent analyses: Incentive contracts, asset ownership, and job design". In: *The Journal of Law, Economics, and Organization* 7.special$_i$*ssue*, pp. 24–52. URL: https://doi.org/10.1093/jleo/7.special_issue.24.

Key, Nigel and McBride, William (2004). "Poultry sector structure, contracts, and technological change". In: *USDA Economic Research Report* 38. URL: https://www.ers.usda.gov/topics/animal-products/poultry-eggs.

Klein, Benjamin and Leffler, Keith B (1981). "The role of market forces in assuring contractual performance". In: *Journal of Political Economy* 89.4, pp. 615–641. URL: https://doi.org/10.1086/260996.

Lafontaine, Francine and Slade, Margaret (2007). “Vertical integration and firm boundaries: The evidence”. In: *Journal of Economic Literature* 45.3, pp. 629–685. URL: https://doi.org/10.1257/jel.45.3.629.

Lerner, Josh and Malmendier, Ulrike (2010). “Contractibility and the Design of Research Agreements”. In: *American Economic Review* 100.1, pp. 214–246. DOI: 10.1257/aer.100.1.214. URL: https://www.aeaweb.org/articles?id=10.1257/aer.100.1.214.

Macchiavello, Rocco and Morjaria, Ameet (2023). “Relational Contracts: Recent Empirical Advancements and Open Questions”. In: *NBER Working Paper Series* 30978. DOI: 10.3386/w30978. URL: https://www.nber.org/papers/w30978.

MacDonald, James M (2014). “Technology, organization, and financial performance in US broiler production”. In: *USDA Economic Research Report* 200. URL: https://www.ers.usda.gov/webdocs/publications/43869/48159_eib126.pdf.

MacDonald, James M and Key, Nigel (2013). “Contracts, markets, and prices: Organizing the production and use of agricultural commodities”. In: *USDA Economic Research Report* 95. URL: https://www.ers.usda.gov/publications/pub-details/?pubid=41704.

MacDonald, James M and Korb, Penni (2004). “Livestock feeding and marketing practices in the United States: Contracts, vertical coordination, and supply chain issues”. In: *USDA Economic Research Report* 27. URL: https://www.ers.usda.gov/webdocs/publications/40764/18614_aer747a_1_.pdf.

Nielsen Company (2022). *Nielsen Consumer Panel Data*. Proprietary dataset. Accessed via Nielsen Company internal portal or licensed database.

Pawelec, Jan (2024). “What is optical sorting and how it works?” In: *Postharvest Technology Review* 12.1, pp. 33–47. URL: https://meyer-corp.eu/article/what-is-optical-sorting-and-how-it-works/.

Pedreschi, M., Mery, D., and Marique, T. (2016). "Grading of potatoes". In: *Computer Vision Technology for Food Quality Evaluation*. Ed. by Da-Wen Sun. 2nd ed. Elsevier, pp. 369–382. URL: http://dx.doi.org/10.1016/B978-0-12-802232-0.00015-3.

Petrin, Amil (2002). "Quantifying the Benefits of New Products: The Case of the Minivan". In: *Journal of Political Economy* 110.4, pp. 705–729. DOI: 10.1086/340779.

Poppo, Laura and Zenger, Todd (2002). "Do Formal Contracts and Relational Governance Function as Substitutes or Complements?" In: *Strategic Management Journal* 23.8, pp. 707–725. DOI: 10.1002/smj.249. URL: https://www.jstor.org/stable/3094289.

Rady, A.M. and Guyer, D.E. (2015). "Rapid and/or nondestructive quality evaluation methods for potatoes: A review". In: *Computers and Electronics in Agriculture* 117, pp. 31–48. URL: http://dx.doi.org/10.1016/j.compag.2015.07.002.

Roberts, Michael J and Schlenker, Wolfram (2016). "Food quality, safety, and technology adoption in US produce markets". In: *American Journal of Agricultural Economics* 98.2, pp. 456–472. URL: https://doi.org/10.1093/ajae/aav073.

Sexton, Richard J. (2013). "Market Power, Misconceptions, and Modern Agricultural Markets". In: *American Journal of Agricultural Economics* 95.2, pp. 209–219. DOI: 10.1093/ajae/aas102. URL: https://doi.org/10.1093/ajae/aas102.

Steven T. Berry, James Levinsohn and Pakes, Ariel (1995). "Automobile Prices in Market Equilibrium". In: *Econometrica* 63.4, pp. 841–890. DOI: 10.2307/2171802. URL: https://www.jstor.org/stable/2171802.

Stockem, J.E., Korontzis, G., Wilson, S., Vries, M.E. de, Eeuwijk, F.A. van, and Struik, P.C. (2022). "Optimal plot dimensions for performance testing of hybrid potato in the field". In: *Potato Research* 65, pp. 417–434. URL: https://doi.org/10.1007/s11540-021-09526-9.

Straight, Michael (2025). *Rooted in uncertainty: Why the agricultural supply chain is ripe for transformation*. https://www.scmr.com/article/rooted-in-uncertainty-why-the-agricultural-supply-chain-is-ripe-for-transformation. Supply Chain Management Review, Accessed September 23, 2025.

Telser, Lester G (1980). "A theory of self-enforcing agreements". In: *Journal of Business*, pp. 27–44. URL: https://www.jstor.org/stable/2352355.

U.S. Department of Agriculture, National Agricultural Statistics Service (2024). *Potatoes 2023 Summary*. Tech. rep. Published September 26, 2024. USDA-NASS. URL: https://www.nass.usda.gov/Publications/Todays_Reports/reports/pots0924.pdf.

U.S. Department of Agriculture, Agricultural Marketing Service (2024). *Seed Potatoes Grades and Standards*. Accessed 2025-08-13. URL: https://www.ams.usda.gov/grades-standards/seed-potatoes-grades-and-standards.

— (2025a). *National Potato and Onion Report*. Accessed 2025-08-14. URL: https://www.ams.usda.gov/mnreports/fvdidnop.pdf.

— (2025b). *Specialty Crops Movement Reports: Fruit and Vegetable Market News*. Accessed: 2025-09-08. URL: https://www.ams.usda.gov/market-news/fruit-and-vegetable-movement-reports.

— (2025c). *Specialty Crops Shipping Point Market Price Reports*. Accessed 2025-08-14. URL: https://www.ams.usda.gov/market-news/fruit-and-vegetable-shipping-point-market-price-reports.

U.S. Department of Agriculture, Economic Research Service (2020). *Loss-Adjusted Food Availability Data System*. Accessed 2025-08-13. URL: https://www.ers.usda.gov/data-products/ag-and-food-statistics-charting-the-essentials/food-availability-and-consumption.

U.S. Department of Agriculture, National Agricultural Library (2024). *Investigating Disease Control Options for Potatoes in Storage*. Tech. rep. Accessed 2025-08-13. U.S.

Department of Agriculture. URL: https://www.nal.usda.gov/research-tools/food-safety-research-projects/investigating-disease-control-options-potatoes-storage.

U.S. Department of Agriculture, National Agricultural Statistics Service (Nov. 2023). *Wisconsin Crop Production Report - November 2023*. Tech. rep. Accessed 2025-08-13. U.S. Department of Agriculture. URL: https://www.nass.usda.gov/Statistics_by_State/Wisconsin/Publications/Crops/2023/WI-Crop-Production-11-23.pdf.

— (Dec. 2024). *North American Potatoes 2024*. Tech. rep. Accessed 2025-08-13. U.S. Department of Agriculture. URL: https://www.nass.usda.gov/Publications/Todays_Reports/reports/uscp1224.pdf.

USDA Economic Research Service (2020). "Loss-adjusted food availability data system". In: *Technical Report*. URL: https://www.ers.usda.gov/data-products/food-availability-per-capita-data-system.

USDA National Agricultural Statistics Service (2024). "North American Potatoes 2024". In: *Technical Report*. URL: https://www.nass.usda.gov/Publications/Todays_Reports/reports/uscp1224.pdf.

Wang, Yi (2025). *Internal potato tuber defects: Hollow heart and heat necrosis*. Accessed September 23, 2025. URL: https://vegpath.plantpath.wisc.edu/2025/09/22/hollow-heart-and-heat-necrosis-of-potato/.

Williamson, Oliver E (1975). "Markets and hierarchies: Analysis and antitrust implications—A study in the economics of internal organization". In: *Free Press*. URL: https://archive.org/details/marketshierarchi00will.