

STANDING OUT: CANNABIS PROCESSOR-RETAILER DYNAMICS IN WASHINGTON  
STATE

A THESIS

Presented to

The Faculty of the Department of Economics and Business

Colorado College

Bachelor of Arts

By

Alex Wimer

March 2023

## **Abstract:**

Previous literature on cannabis and new markets suggests that scale is a significant advantage to firms. This paper investigates whether if in the low market power environment of cannabis processors in the Washington cannabis industry, the advantage of scale still applies. Using Washington's seed-to-sale database I investigate the link between processor firm size, measured through a dummy variable categorizing between firms with one facility vs more than one, and specialization of product assortment to processors' number of unique relationships with retailers. My results indicate conclusions generally in line with intuition, that greater processor size and specialization in products like solid and liquid edibles yield more unique relationships.

## **Section 1: Introduction**

The US cannabis industry, being illegal at the federal level but legal in select states, has a range of materially disconnected (i.e. interstate commerce restricted) competitive environments with varying degrees of market concentration. State regulators have adopted different approaches to legalization, requiring or banning vertical integration (firms owning all levels of their supply chain from production to processing to final point of sale), restricting outside investment, requiring in-state residency for ownership, etc. Each state's approach has limitations and advantages, where all states are attempting to lay the groundwork for a federally legalized system.

Generally, the supply structure of the recreational cannabis industry flows from cultivation (producers) to lab testing and extraction, to processing, and ultimately to retail firms and consumers. Market power can be differently distributed at vertical levels across states, but

typically retail firms are coveted for their relatively larger profit margins unless there are other constraints like loose controls on license requirements (e.g. California), limitations on other vertical level licenses, etc. In environments with dominant retail power, competition is intense between non-retail firms and operations potentially unsustainable.

The question then is given concentration of power to retailers, what strategies or obstacles should firms higher in the vertical consider? Each market is unique but an examination of one might yield practical implications for others. The scope of this paper concerns Washington state, and the positioning and interaction of processors with retailers. Processors are selected due to their direct relationships with retailers and position of low market power in this environment, competing for business with a relatively lower number of license limited retailers. An investigation of what characteristics of processors yield greater number of relationships with retailers could help processor firms in other states understand how to better differentiate from competitors and gain more traction in their markets.

Grounded in relevant literature, my hypothesis is that processors with a larger number of facilities and specialized assortments will earn more relationships with retailers, large and small. Large chain retailers who are concerned with having greater assortments but have price sensitive consumers will want to buy from suppliers who can produce consistent, differentiated products with relatively low prices to allow retailers to maintain competitively low margins and dominant market power. Those processors who can earn more relationships will be positioned better in the short and long term, capturing more orders for their products from retailers, outlasting competitors, and establishing brand value to a broader range of potential consumers.

The dataset being analyzed was acquired through cooperation with Professor Brett Hollenbeck and the Washington Cannabis and Liquor Board (WSCLB). The WSCLB maintains a seed-to-sale (producer, to processor, to retail, to consumer) transaction database for regulatory purposes which, unlike any other rec legal state that maintains such a system, is publicly available upon request. The data contains identification numbers for all active firms which when related to applicant lists obtainable through WSCLB public records allows identification of firm-level transactions.

Through a robust regression on the transaction data, I expect to show that processor multifacility status and processor-product assortment and relative assortment price has a statistically significant positive impact on number of unique relationships between processors and retailers.

The next section, section two, begins with a review of the literature that exists regarding the importance of scale in nascent retail centric markets, the implications of concentrated retail market power on processors in the cannabis industry, and the dynamics of supplier-retailer relationships when there are varying levels of processor brand strength. This analysis establishes the groundwork for our theoretical model, section three, which is adapted from similar premises in reviewed models and common principles. This approach is taken to produce simple interpretable results that can be used as guidelines for practical applications. The following section, section four, describes the seed-to-sale data and its origin in greater detail, provides reasoning for selected period of analysis, and outlines the variable components that will be regressed onto the unique relationships between processors and retailers. Section five provides the results of the robust regression model, including tests for multicollinearity, skewness, kurtosis, etc. as well as a reflection on limitations and possible alterations to improve goodness of fit and other characteristics. I conclude the paper with section 6, discussing the importance of

scale in developing long-term retail relationships and its theoretical implications for positioning upstream firms in more advantageous positions.

## **Section 2: Literature Review**

Within the U.S. cannabis industry, there is a strong sentiment that bigger is better. Despite the current federal illegality of the industry, many firms have opted towards rapid scaling, spreading within or across states to access fragmented local and regional markets and achieve a dominant market share. In-state firms and multi-state operators (MSOs) attempt to leverage varying levels of access to capital, brand recognition, and sophisticated management across differing state regulatory environments to build a foundation for eventual federal legalization.<sup>1</sup> State regulators have taken varying stances, encouraging vertical integration and outside capital or shielding state industry to foster local entrepreneurship.

Prior academic studies of the US cannabis industry dynamics have focused on the Washington market, using the state's uniquely publicly available seed-to-sale database to investigate impacts of state policy and industry behaviors. The intuition for this research is grounded in work done by Brett Hollenbeck (2021) on Washington retail firm sizes' (i.e. multistore or single) relationship with firms' profits.<sup>2</sup> The analysis determines a positive relationship between size and market power, and emphasizes that counterintuitively, multistore firms who offer a larger

---

<sup>1</sup> "The Cannabis Industry's Multi State Operators," Cannabis Growth Funds, May 28, 2021, <https://www.cannabisgrowthfunds.com/the-cannabis-industrys-multi-state-operators/>.

<sup>2</sup> Renato Giroldo and Brett Hollenbeck, "Winning Big: Scale and Success in Retail," *SSRN Electronic Journal*, 2020, <https://doi.org/10.2139/ssrn.3613183>.

product assortment attract price-sensitive consumers and set lower prices to generate relatively larger profits to single store firms. This result is ambiguous in the literature, higher assortments typically paralleling increased prices.<sup>3</sup> The analysis also suggests that those multistore firms which achieve greater profits through returns to scale did not become multistores through being higher quality management (firms assigned number of licenses based off random lottery chances/number of license applications with max of 3 licenses per firm), and that obstacles to growth from single to multistore such as access to capital will be significant barriers. The combination of larger retail firms offering more benefits to consumers and small retail firms having significant barriers to growth indicates that market concentration is an eventual outcome, especially given the limit on licenses. Therefore, those firms which can secure capital and have influential enough reputations to offset consumer loss to larger firms or operate long enough at a loss to build a consumer base may be able to compete and eventually outperform smaller retail firms.

This raises the question of how these dynamics impact firms higher in the vertical, processors and producers. There are no limitations on the number of total available processor and producer licenses in Washington. Consequently, processors and producers are not afforded the same competitive advantages as retail firms for first mover advantages though the normal benefits apply. Processor firms have fewer barriers to entry and must contend with more competition from somewhat homogeneous firms, resulting in downward pressure on processors' margins and

---

<sup>3</sup> Simon P. Anderson and Andre Palma, "Market Performance with Multiproduct Firms," *Journal of Industrial Economics* 54, no. 1 (2006): pp. 95-124, <https://doi.org/10.1111/j.1467-6427.2006.00277.x>; Jaehwan Kim, Greg M. Allenby, and Peter E. Rossi, "Modeling Consumer Demand for Variety," *Marketing Science* 21, no. 3 (2002): pp. 229-250, <https://doi.org/10.1287/mksc.21.3.229.143>.

relatively low price dispersion across firms.<sup>4</sup> Asymmetry in price setting power between large retailers and processors theoretically, “could cause a preference towards technologies which increase large buyers’ buyer power and result in higher prices for smaller buyers”.<sup>5</sup> Given processor regulatory requirements for linear pricing - firms selling each unit of their products to retailers at consistent prices independent of total volume sold (no vertical contracts or slotting allowances) - this specialization towards serving only large retail interests is not necessarily true. Determining whether processor-product retail preferences differ across differently sized processor firms could help inform whether the asymmetrical market power between downstream and upstream has potential spillover effects on smaller firms and ultimately consumers.<sup>6</sup> While aforementioned research by Hollenbeck shows that large retail firms reduce prices for consumers to create greater overall profits for the retailer relative to smaller competitors, Hollenbeck notes that increased competition and reduced market power for retailers would also lower prices and generate more tax revenue.<sup>7</sup>

Understanding reputation/brand effects for both retailers and processors on working relationships is also critical in understanding the effects of market power. Literature shows that suppliers with strong brands exercise market power in relationships with suppliers, impacting retail promotional

---

<sup>4</sup> Brett Hollenbeck and Kosuke Uetake, “Taxation and Market Power in the Legal Marijuana Industry,” *SSRN Electronic Journal*, 2018, <https://doi.org/10.2139/ssrn.3237729>.

<sup>5</sup> Howard W. Smith and John E. Thanassoulis, “Upstream Competition and Downstream Buyer Power,” SSRN, October 11, 2006, <https://ssrn.com/abstract=936712>.

<sup>6</sup> Paul W. Dobson et al., “Buyer Power and Its Impact on Competition in the Food Retail Distribution Sector of the European Union,” *Journal of Industry, Competition and Trade* 1, no. 3 (2001): pp. 247-281, <https://doi.org/10.1023/a:1015268420311>.

<sup>7</sup> Hollenbeck and Uetake, “Taxation and Market Power”

strategies and requiring less contribution from retailers for sales. Retailers can respond by sourcing greater volumes of private label i.e. generic products, reducing dependence on suppliers.<sup>8</sup> This runs into whether consumers have strict brand preferences and/or low search costs and would respond by looking for the same product across other stores, which seems to not be the case.<sup>9</sup> However, this could be more of an indicator of the immature state of the market where consumer preferences are not yet defined. Considering the asymmetric power dynamic between downstream and upstream firms, processor-retailer product relationships hinge on how each retailer interpret processor brand contributions. Also given the relationship defined in previous literature between supplier exposure to strong retail brands and consequent proliferation of additional business with weaker retail brands in subsequent periods, suppliers i.e. processors have strong incentives to work with dominant retail brands to build their client lists. Additionally, those suppliers which serve a more diversified retail base, as opposed to a concentrated few firms, have higher chances of obtaining more orders.<sup>10</sup>

### **Section 3: Theory**

The theory for our model of analysis derives initially from the fixed effects model described by Hollenbeck, which relates retail firm profits to multistore status and control

---

<sup>8</sup> Mark Glynn, “How Supplier Brand Benefits Affect Retailer’s Willingness to Invest.,” accessed March 25, 2023, <https://www.impgroup.org/uploads/papers/8111.pdf>.

<sup>9</sup> Hollenbeck and Uetake, “Taxation and Market Power”

<sup>10</sup> Alessandro Manello and Giuseppe Calabrese, “The Influence of Reputation on Supplier Selection: An Empirical Study of the European Automotive Industry,” *Journal of Purchasing and Supply Management* 25, no. 1 (2019): pp. 69-77, <https://doi.org/10.1016/j.pursup.2018.03.001>.



variables market, time, age and number of applications per firm. The paper identifies the importance of firm scale in allowing for differentiation in new, entrepreneurial markets, particularly retail, but the concepts introduced seem applicable to upstream operations.<sup>11</sup>

Analysis by Hollenbeck in another of his papers that suggests that there is low wholesale price dispersion, relatively similar wholesale market share allotment to each processor by retailers (~8%), and retailers on average having a multiple of the number of relationships that processors have, prompts investigation into possible differentiation among processors.<sup>12</sup>

I consider Hollenbeck's treatment of multistores in the new context of processors, where an increase in number of facilities, that is a firm being a multistore, would allow for potentially more brand exposure and greater number of retail clients of both multistore and single store types. I include a weighted average product unit price to determine in addition to multistore status how specialization and therefore brand plays a role in increasing business for processor firms. The model contains three main assumptions.

Foremost, that the dependent variable, total number of unique relationships between each processor and retailers, reflects meaningful information on differentiation between processors. That is, number of relationships between a processor and retailers in a market where processors are seen by most retailers as homogeneous is an indicator of trust and impact of brand and relates to potentially higher overall number of orders and therefore an indicator of competitive processor

---

<sup>11</sup> Girollo and Hollenbeck, "Winning Big"

<sup>12</sup> Hollenbeck and Uetake, "Taxation and Market Power"

differentiation. This is my own assumption grounded in reviewed literature on supplier-retailer relationships and brand impact.<sup>13</sup>

Second, that defined exogenous variables in the model are based on and interpreted in the lens of firms' long-term strategies (multi-facility, brand assortment, and pricing to match costs) and are important across the lifetime of a processor and that a lack of a time series element, while impacting our ability to make stronger than association claims and ground our results in market fluctuations, does not hinder the practical implications of our results.

Third, that those firms which are multi-facility potentially have differing relationship outcomes at least in part because of their scale and are not empowered to become multi-facilities because of better outcomes than other processors. That is, multi-facilities are also a contributing factor to accumulating relationships and not solely an outcome of having accumulated more relationships. This is a large assumption, but necessary to evaluate the data given only two applicant periods (2014 and 2018) where processor multifacility status changes cannot be observed and related to transaction data.

Beyond my assumptions, the model is limited in its inability to further contextual the transaction data within differences of firm operator sophistication, disparities in access to capital markets, and other non-transaction level related factors. These could explain non-captured variance in the data and complicate our interpretations. Additionally as mentioned, the model is limited by the lack of a time series component.

---

<sup>13</sup> “The Power of Trust in Manufacturer-Retailer Relationships,” Harvard Business Review, August 1, 2014, <https://hbr.org/1996/11/the-power-of-trust-in-manufacturer-retailer-relationships>.

## **Section 4: Data and Methodology**

This section describes the data, the origin of the data, and methodology of analysis. For the purposes of this study, data from the Washington seed-to-sale database has been examined, acquired through cooperation with Brett Hollenbeck and the Washington Cannabis and Liquor Board. The seed-to-sale database is a comprehensive regulatory registry that records all cultivation, processing, retail transaction data of cannabis products. All transactions are linked to firm license numbers and firm identifier IDs, providing transparency on all levels of transaction processes. The state has employed a seed-to-sale system since the fall of 2013 and has changed vendors multiple times by 2023. The current system is state developed and run.

The Washington seed-to-sale data was selected for four primary reasons: the incredible detail and depth of the database, accessibility relative to other non-publicly available state seed-to-sale systems, Washington's unique regulatory structure, and abundance of economic literature that has made use of the same database.

The data analyzed ranges from 2014 to early 2018. The data is being analyzed for this period to capture changes in behavior in varying market conditions (inception of market to mature market). Data exists for 2018 to 2023 and while possible to reconcile the systems, it was deemed unnecessary given the large volume of transaction data already provided.

From Hollenbeck, I received applicant data for two periods, 2014 and 2018 and state-wide inventory transfer data from 2014 to 2017. The applicant data lists all applicants/license holders and their license statuses of those two periods, those who have been denied a license, are pending WSLCB review, approved and pending, and approved/active. There are a much larger

number of applicants/licenses in 2018 than 2014 as 2018 includes active firms (while 2014 could only include the market's first applicants), and the total number of available licenses was raised by 2018 due to an increase in the license cap from 334 to 556. The transaction dataset contains 1,048,576 transactions between producers and processors, processors to processors, processors to retailers, and retailers to consumers, displaying product information and numerical buyer and seller identifiers. These transactions represent a random subset of a total 80 million transactions in that period.

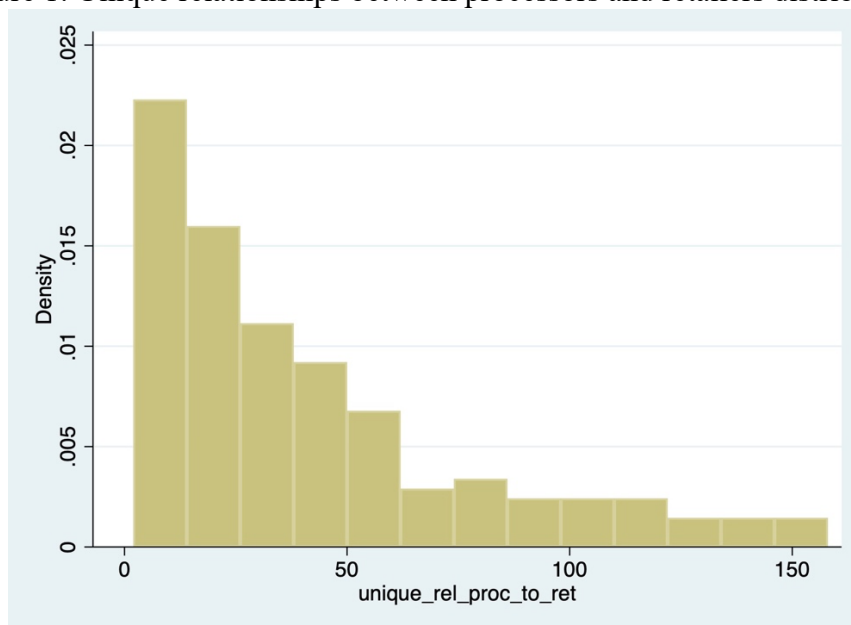
The applicant data is filtered to only accepted firms (active licenses) and separated into categories of multi-facility and single facility license holders for processing, manufacturing, and retail operations. Multi-facility firms are identified through the applicant lists, grouped as a multi-facility assuming a firm actively operates more than one facility or store across the same horizontal position (e.g., a processing firm owning multiple processor facilities, a retailer owning multiple retail stores, etc.). Vertically integrated operations are identified within processors and producers with a similar approach. As stated, in Washington only processors and producers can be owned by the same entity with retailers excluded.

Originally, multi-state operators (MSOs), firms which own multiple operations nationally and have stronger institutional connections than most local firms, were intended to be included in our analysis to control for access to capital markets which is otherwise unobservable in our data. The multi-state operators were identified primarily by industry press releases and articles, resulting in six MSOs being recorded. MSO effects on firm data was deemed to be limited due to small sample size, and that those firms which underwent mergers to become MSOs only did so in the very late stages of the observed time period. Consequently, the term was omitted. The MSO transaction data was located through each firm's Unique Business

Identifier (UBI), a 9-digit number issued to individuals and companies doing business in the State of Washington, and firm license number.

Applicant data from 2014 and 2018 are appended and duplicates removed. Applicant information (name, market, firm type) are merged with inventory transfer data through relating UBI and license numbers. Outbound and inbound firms (sellers and buyers) are identified for each transaction; outbound processor and inbound retailer transactions are separated from the larger dataset. Unique outbound processor- inbound retailer relationships are identified by concatenating the outbound and inbound id variables and sorting and counting by outbound. The unique relationship processor-to-retailer variable is shown in Figure 1 as having a right-skewed distribution. The variable is logarithmically transformed to introduce normality.

Figure 1: Unique relationships between processors and retailers distribution



Unique relationships between processors and retailers are modeled through adapting Hollenbeck's expression for retail profits to introduce variation within multi and single-facility processor firms and to acknowledge controlling fixed effects.

$$\ln(U) = \alpha + \beta_1 Multi + \beta_2 VertInt + \beta_3 Multi * VerInt + \sum (\beta_{ij} * MeanUnitPrice_i * ProductTypeConcentration_j) + \varepsilon$$

This robust regression parallels Hollenbeck's but excludes his control for the number of applications filed as processors do not face license restrictions or lotteries. Our dependent variable,  $\ln(U)$  is the natural log of total unique processor to retailer connections from 2014-2018. A dummy variable value of 1 is assigned to all multi-facility firm data (or 0 if non-multi-facility). A dummy variable value of 1 is assigned to all vertically integrated processor-producer firm data (or 0 if non-vertically integrated). An interaction effect between multifacility and vertical integration is included as theoretically a processor being vertically integrated will have some impact on the effect of the multifacility variable on number of captured relationships. A vertical integrator may be able to leverage more facilities with lower friction in acquiring wholesale product i.e. sourcing costs and trust, greater understanding of market dynamics, and longer established industry connections as vertical integrators were more common before the implementation of a final 37% retail tax. Therefore, the predicted positive effect of being a multifacility (as opposed to single) on number of relationships would be amplified, with multifacility showing an even greater increase in retail relationships over single facility processors compared to non-vertically integrated processors. It should be noted that under Washington policy, there can be no vertical integration between retail firms and processors or producers, which the model reflects.

Table 2: Price-Product Concentration Interaction Terms

| Variable            | Obs | Mean   | Std. Dev. | Min | Max    |
|---------------------|-----|--------|-----------|-----|--------|
| mean unitprice22    | 172 | .437   | 1.544     | 0   | 9.007  |
| mean unitprice23    | 172 | .375   | 2.021     | 0   | 13.725 |
| mean unitprice24    | 172 | 6.821  | 6.101     | 0   | 34.833 |
| mean unitprice25    | 172 | .708   | 2.667     | 0   | 15.312 |
| mean unitprice28    | 172 | 11.551 | 6.6       | 0   | 50.887 |
| mean unitprice31 32 | 172 | 1.635  | 4.614     | 0   | 31.895 |
| t22 of total        | 172 | .04    | .163      | 0   | 1      |

|                 |     |      |      |   |      |
|-----------------|-----|------|------|---|------|
| t23 of total    | 172 | .007 | .059 | 0 | .726 |
| t24 of total    | 172 | .139 | .257 | 0 | 1    |
| t25 of total    | 172 | .009 | .076 | 0 | .967 |
| t28 of total    | 172 | .794 | .323 | 0 | 1    |
| t31 32 of total | 172 | .012 | .054 | 0 | .499 |

Within the model, the variables MeanUnitPrice (e.g. mean\_unitprice22) and ProductTypeConcentration (e.g. t22\_of\_total) are represented jointly by their product, an interaction term named Weighttype (e.g. Weighttype22). The interaction term can be defined as the product of average unit price of each firm for a product type with each firms respective percentage of transactions of a product type out of their total transactions. Product types for processor-to-retailer transactions come mainly in six categories, described through the seed-to-sale system manual.<sup>14</sup> Type 22 is solid edible, type 23 is liquid edible, type 24 is extract for inhalation, type 25 is topical, type 28 is usable product, and type 31 and 32 are both packed and infused mix respectively (regarded as the same type for our analysis). The product is an interaction term to describe the impact of level of product type concentration on the relationship between processor average product unit prices and unique processor-retailer relationships, or vice versa. Processors with varying focus of product assortment may have different costs to producing their products due to scale or differing brand effectiveness because of less or more product focus, which will impact pricing of their products. Likewise, processors may see opportunities in wholesale prices of certain products and respond by focusing production and sales on those product types. Therefore, combining both these variables to a single term

---

<sup>14</sup> Brett Hollenbeck, “Cannabis Data.zip,” Dropbox, accessed March 24, 2023, [https://www.dropbox.com/s/2ths5zgdrgo7xnf/Cannabis%20data.zip?dl=0&file\\_subpath=%2FCannabis%2Bdata](https://www.dropbox.com/s/2ths5zgdrgo7xnf/Cannabis%20data.zip?dl=0&file_subpath=%2FCannabis%2Bdata).

improves VIF and reduces multicollinearity but makes results less interpretable unless assumptions are made that one input is more tractable.

## Section 5: Analysis and Results

Table 3: Model Summary Statistics

| Variable             | Obs | Mean   | Std. Dev. | Min  | Max    |
|----------------------|-----|--------|-----------|------|--------|
| logunique rel proc~t | 172 | 3.275  | 1.011     | .693 | 5.063  |
| VertInt              | 172 | .174   | .381      | 0    | 1      |
| Multi                | 172 | .058   | .235      | 0    | 1      |
| weighttype22 meanu~e | 172 | .245   | 1.073     | 0    | 9.007  |
| weighttype23 meanu~e | 172 | .072   | .602      | 0    | 7.144  |
| weighttype24 meanu~e | 172 | 1.63   | 3.339     | 0    | 16.997 |
| weighttype25 meanu~e | 172 | .085   | .792      | 0    | 10.219 |
| weighttype28 meanu~e | 172 | 10.097 | 6.742     | 0    | 50.887 |
| weighttype31 32 me~e | 172 | .084   | .454      | 0    | 5.589  |

Table 3 shows our model's summary statistics. The transaction data has been reduced from total processor-retailer transactions to non-duplicate processor data entries of our variables. This allows for analysis without bias in the regression due to changes in weight for different firms, no inflation in sample size which would be the consequence of using our current variables on the original set, no artificially reduced variability, and reduced risk of overfitting the data.

Table 4: Model Regression Results

|                          | Coef. | St.Err. | t-value | p-value | [95% Conf | Interval] | Sig |
|--------------------------|-------|---------|---------|---------|-----------|-----------|-----|
| logunique_rel_pro<br>c~t |       |         |         |         |           |           |     |
| VertInt                  | .357  | .17     | 2.10    | .037    | .022      | .693      | **  |
| Multi                    | .964  | .209    | 4.61    | 0       | .551      | 1.378     | *** |
| VertInt#Multi            | -.677 | .326    | -2.08   | .039    | -1.32     | -.034     | **  |
| weighttype22_me<br>anu~e | .204  | .066    | 3.08    | .002    | .073      | .335      | *** |
| weighttype23_me<br>anu~e | .165  | .05     | 3.32    | .001    | .067      | .263      | *** |
| weighttype24_me<br>anu~e | .083  | .016    | 5.30    | 0       | .052      | .114      | *** |



|                          |         |                      |         |      |       |       |     |
|--------------------------|---------|----------------------|---------|------|-------|-------|-----|
| weighttype25_me<br>anu~e | .053    | .025                 | 2.17    | .031 | .005  | .102  | **  |
| weighttype28_me<br>anu~e | -.037   | .009                 | -4.23   | 0    | -.054 | -.02  | *** |
| weighttype31_32_<br>me~e | .192    | .084                 | 2.28    | .024 | .025  | .359  | **  |
| Constant                 | 3.319   | .156                 | 21.22   | 0    | 3.01  | 3.628 | *** |
| Mean dependent var       | 3.275   | SD dependent var     | 1.011   |      |       |       |     |
| R-squared                | 0.348   | Number of obs        | 172     |      |       |       |     |
| F-test                   | 21.391  | Prob > F             | 0.000   |      |       |       |     |
| Akaike crit. (AIC)       | 437.294 | Bayesian crit. (BIC) | 468.769 |      |       |       |     |

\*\*\*  $p < .01$ , \*\*  $p < .05$ , \*  $p < .1$

Table 4 describes our robust regression of log of unique relationships of processors with retailers regressed onto variables of multifacilitye, vertical integration, and weighted prices by product firm assortment. As the response variable is log-transformed, coefficients on the predictor variables represent percent changes in the response variable. The relationship between the dummy variables and response variable is simple to interpret whereas the weight types require more explanation. As weight types describe the product of firms' respective average product-type prices with their relative concentration of assortments, we can interpret a unit increase in this term as either an increase in concentration of assortment, price of product type, or combination of which could be explained by their interconnected natures. Given earlier examination of processors as operators in a competitive market, pricing mark ups positively increasing number of relationships seems very unlikely. Concentration of assortment appears more plausible, the material costs to production changes more in the control of processor firms than prices negotiated with retailers.

The R-squared of the model is output as 0.348, indicating low explanatory power of my predictors on the variance of log unique relationships between processors and retailers. Through the Ramsey RESET test (omitted variable bias test), we fail to reject the null hypothesis that there are omitted variables. This does not mean I have strong explanatory power, but rather that

there is insufficient evidence to suggest I have omitted variables from my model. As established in the theory, the model cannot act on data unrepresented in the dataset (capital access, firm sophistication, etc.).

There are five variables significant at the .01 significance level: Multifacility, and Weighttype22, 23, 24, and 28. Vertical integration, the interaction effect between vertical integration and multifacility, and Weighttype22 and 25 are significant at the .05 significance level. Most predictor variables describe positive relationships with the response variable except for the multifacility-vertical integration interaction effect and Weighttype28.

Positive multifacility status has the largest impact on unique relationships, yielding a 96.4% increase. The near doubling of relationships is logical in that having an additional similar facility would potentially double production and extend firm reach to more retailers. By magnitude, the interaction term has the second largest impact, simultaneous multifacility and vertical integration status reducing unique number of relationships by 67.7%. This effect does not line up with our expected results. Vertical integration, as according to our hypothesis, corresponds with a 35.7% increase in the response variable. This disparity could potentially be attributed to differences in multifacility-vertically integrated firms strategy to multifacility, negative impacts on vertical integrators as a consequence of the final retail tax change in 2015, or other factors. Given the structure of the data, it is difficult to determine the cause of disparity.

Weighttype 22 i.e. solid edibles, has the largest impact of the Weighttype variables with a unit increase in the variable yielding a 20.4% increase in number of unique relationships. This describes a possible retailer preference towards solid edibles and/or insensitivity to changes in price due to processor ability to largely differentiate products from competitors with many possible outputs. Weighttype31\_32, a mix, follows closely with an 19.2% increase. As there is

less consistency to the form of this product, this could be reflective of inherent volatility in pricing and not necessarily insensitivity by retailers to high pricing or want for higher concentration. Weighttype23, liquid edible, has 16.5% increase in the response variable with a unit increase.

Weighttype24 and 25, extract for inhalation and topicals, contribute 8.3% and 5.3% increases respectively to the response variable with a unit increase. This could be seen as both a sensitivity to price and relative need for these products. A unit increase in Weighttype 28, usable, causes a 3.7% decrease in unique number of relationships, a relatively small relationship. This is possibly representative of an overabundance of the usable product, which is quite generic, and sensitivity of retailers to pricing.

Multifacility evidently has large impact on number of unique relationships between processors and retailers, lending credence to part of my hypothesis. Solid and liquid edibles as well as mix products also seem to have a strong relationship with the response variable, likely describing that those products have strong returns to specialization over the others.

Table 5: Pairwise correlations

| Variables                  | (1)    | (2)    | (3)    | (4)    | (5)    | (6)    | (7)    | (8)    | (9)   |
|----------------------------|--------|--------|--------|--------|--------|--------|--------|--------|-------|
| (1) logunique_rel_t        | 1.000  |        |        |        |        |        |        |        |       |
| (2) vertical_outbound      | 0.142  | 1.000  |        |        |        |        |        |        |       |
| (3) multifacility_outbound | 0.142  | 0.082  | 1.000  |        |        |        |        |        |       |
| (4) weighttype22_mce       | 0.291  | 0.055  | 0.042  | 1.000  |        |        |        |        |       |
| (5) weighttype23_mce       | 0.164  | 0.003  | -0.030 | 0.162  | 1.000  |        |        |        |       |
| (6) weighttype24_mce       | 0.364  | -0.039 | -0.063 | -0.051 | -0.011 | 1.000  |        |        |       |
| (7) weighttype25_mce       | 0.077  | 0.175  | -0.027 | -0.012 | -0.013 | -0.038 | 1.000  |        |       |
| (8) weighttype28_mce       | -0.445 | -0.039 | 0.144  | -0.290 | -0.169 | -0.456 | -0.127 | 1.000  |       |
| (9) weighttype31_3c        | 0.132  | -0.041 | 0.024  | -0.036 | -0.022 | 0.087  | -0.011 | -0.128 | 1.000 |

Table 6: Variance inflation factor

|                          | VIF   | 1/VIF |
|--------------------------|-------|-------|
| 1.vertical outbound      | 1.145 | .873  |
| 1.multifacility outbound | 1.439 | .695  |
| 1.vertical outbound      | 1.568 | .638  |

|                      |       |      |
|----------------------|-------|------|
| weighttype22 meanu~e | 1.202 | .832 |
| weighttype23 meanu~e | 1.054 | .949 |
| weighttype24 meanu~e | 1.356 | .737 |
| weighttype25 meanu~e | 1.069 | .935 |
| weighttype28 meanu~e | 1.592 | .628 |
| weighttype31 32 me~e | 1.03  | .971 |
| Mean VIF             | 1.273 | .    |

The model's predictor variables are robust against multicollinearity, as identified through Tables 5 and 6. The inclusion of only the interaction term between mean unit price and product assortment concentration (i.e. weighttype22, 23, etc.) and not the individual variables, while reducing interpretability, contributes largely to reducing the model's VIF.

The normality and homoscedasticity of the model are addressed through logarithmic transformation of the response variable and use of robust for our regression. Alternative methods such as weighted regression were attempted but ultimately robust yielded the best  $R^2$  and interpretability. Z-score standardized values were calculated for the mean unit price-assortment concentration interaction - z-score standardized values assigned to both variables and an interaction term created out of the product - to normalize both variables' distributions however the resulting regression had low  $R^2$ , higher VIF, higher MSE, etc. Ultimately, it seems the transformations cause a key loss of information, namely outliers whose variability is important to our predictions.

## Section 6: Discussion

As this analysis found, scale matters. Processors with greater number of facilities have greater total number of clients, and specialization in products, especially edibles and potentially mix products, can contribute to this number. In an environment seemingly lacking differentiation, processors who can think long term and produce alternative products at larger

scales will be the strongest contenders by number of potential clients. These results have implications for all forms of supplier-retailer relationships in new markets, potentially describing how early scaling and specialization allow for more capable positioning of suppliers to retailers when there is eventual retail market concentration. Being a known quantity in a specific market allows for increases in familiarity with retailer clients, development of consumer base for products, and visibility to non-clients. Other practical implications could be that suppliers signaling consistent production capacity and product focus increases incentives for retailers to work with them, reducing their capacity risk.<sup>15</sup>

Regarding further research, my model was limited in a few key ways. The model lacks a time series element. The inclusion of control for time and age would allow greater specificity as to the interplay of product volume and price. Greater knowledge of the flow of products at certain periods considered next to firms' output and product assortment concentration would clarify interpretations of coefficients (i.e. is price or volume contributing more) on weight type variables. The time series element would affect the multifacility and vertical integration variables as well. A tax change to a final 37% retail tax was implemented in 2015 which affects the impact of vertical integration from 2014-2015 vs 2015-2017. Multifacility and non-multifacility processors could be related at different periods to determine if their relationship to unique number of processor-retailer relationships was consistent in different market conditions (new to mature). Although unavailable, the data would also be enhanced by applicant data from 2015,

---

<sup>15</sup> Fei Qin et al., "Role of Random Capacity Risk and the Retailer in Decentralized Supply Chains with Competing Suppliers," *Decision Sciences* 45, no. 2 (2014): pp. 255-279, <https://doi.org/10.1111/deci.12067>.

2016, and 2017. This would allow for better understanding on how gaining multifacility status affects firm performance by relating before and after rates of gaining unique relationships.

Future research could also include relating multi-state operators to our dataset as an instrument for access to capital. This would require data past 2018, and could yield interesting results as to the impact of capital on number of unique relationships and outside capital access's interaction effects with multifacility status.

## Bibliography:

- Allain, Marie-Laure. "The Balance of Power between Producers and Retailers ; a Differentiation Model." *Recherches économiques de Louvain* 68, no. 3 (2002): 359.  
<https://doi.org/10.3917/rel.683.0359>.
- Amlung, Michael, Derek D. Reed, Vanessa Morris, Elizabeth R. Aston, Jane Metrik, and James MacKillop. "Price Elasticity of Illegal versus Legal Cannabis: A Behavioral Economic Substitutability Analysis." *Addiction* 114, no. 1 (2018): 112–18.  
<https://doi.org/10.1111/add.14437>.
- Anderson, Simon P., and Andre Palma. "Market Performance with Multiproduct Firms." *Journal of Industrial Economics* 54, no. 1 (2006): 95–124. <https://doi.org/10.1111/j.1467-6427.2006.00277.x>.
- Argentesi, Elena, Roberto Cervone, Tomaso Duso, and Alessia Marrazzo. "The Effect of Mergers on Variety in Grocery Retailing." *SSRN Electronic Journal*, 2021.  
<https://doi.org/10.2139/ssrn.3867051>.
- Armstrong, Michael J. "Legal Cannabis Market Shares during Canada's First Year of Recreational Legalisation." *International Journal of Drug Policy* 88 (2021): 103028.  
<https://doi.org/10.1016/j.drugpo.2020.103028>.
- Borle, Sharad, Peter Boatwright, Joseph B. Kadane, Joseph C. Nunes, and Shmueli Galit. "The Effect of Product Assortment Changes on Customer Retention." *Marketing Science* 24, no. 4 (2005): 616–22. <https://doi.org/10.1287/mksc.1050.0121>.
- "Buyer Power and Competition in European Food Retailing." *International Journal of Retail & Distribution Management* 31, no. 9 (2003): 477–77.  
<https://doi.org/10.1108/09590550310491450>.
- "The Cannabis Industry's Multi State Operators." Cannabis Growth Funds, May 28, 2021.  
<https://www.cannabisgrowthfunds.com/the-cannabis-industrys-multi-state-operators/>.
- Caulkins, Jonathan P., Yilun Bao, Steve Davenport, Imane Fahli, Yutian Guo, Krista Kinnard, Mary Najewicz, Lauren Renaud, and Beau Kilmer. "Big Data on a Big New Market: Insights from Washington State's Legal Cannabis Market." *International Journal of Drug Policy* 57 (2018): 86–94. <https://doi.org/10.1016/j.drugpo.2018.03.031>.
- Chavez, Daniel Eduardo, and Haipeng (Allan) Chen. "First-Mover Advantages and Innovation Success: A Contingency Approach." *Journal of Business & Industrial Marketing* 37, no. 6 (2021): 1169–81. <https://doi.org/10.1108/jbim-03-2021-0165>.
- Chen, Zhijun, and Patrick Rey. "Loss Leading as an Exploitative Practice." *American Economic Review* 102, no. 7 (2012): 3462–82. <https://doi.org/10.1257/aer.102.7.3462>.

- Childs, Jason, and Angèle Poirier. “Implications of Marijuana Purchase Task Based Demand Functions for Optimal Legal Pricing of Cannabis.” *International Journal of Drug Policy* 95 (2021): 103271. <https://doi.org/10.1016/j.drugpo.2021.103271>.
- Childs, Jason, and Jason Stevens. “A Cannabis Pricing Mistake from California to Canada: Government Can’t Tax Cannabis Optimally.” *Applied Economics Letters* 28, no. 9 (2020): 779–83. <https://doi.org/10.1080/13504851.2020.1781764>.
- Childs, Jason, and Jason Stevens. “The State Must Compete: Optimal Pricing of Legal Cannabis.” *Canadian Public Administration* 62, no. 4 (2019): 656–73. <https://doi.org/10.1111/capa.12352>.
- Choi, S. Chan. “Price Competition in a Channel Structure with a Common Retailer.” *Marketing Science* 10, no. 4 (1991): 271–96. <https://doi.org/10.1287/mksc.10.4.271>.
- Cui, Tony Haitao, Guangwen Kong, and Behrooz Pourghannad. “Is Simplicity the Ultimate Sophistication? the Superiority of Linear Pricing.” *Production and Operations Management* 29, no. 7 (2020): 1767–88. <https://doi.org/10.1111/poms.13183>.
- Dobson, Paul W., Roger Clarke, Stephen Davies, and Michael Waterson. “Buyer Power and Its Impact on Competition in the Food Retail Distribution Sector of the European Union.” *Journal of Industry, Competition and Trade* 1, no. 3 (2001): 247–81. <https://doi.org/10.1023/a:1015268420311>.
- “Economies of Scale in the Production of Cannabis Final Revised.” Accessed March 25, 2023. <https://lcb.wa.gov/publications/Marijuana/BOTEC%20reports/5c-Economies-of-Scale-in-the-Production-of-Cannabis-Final-Revised.pdf>.
- Freeman, Tom P., Teodora Groshkova, Andrew Cunningham, Roumen Sedefov, Paul Griffiths, and Michael T. Lynskey. “Increasing Potency and Price of Cannabis in Europe, 2006-16.” *Addiction* 114, no. 6 (2019): 1015–23. <https://doi.org/10.1111/add.14525>.
- Garriga, Carlos, Fernando Sanchez Losada, and Javier Coto-Martínez. “Optimal Taxation with Imperfect Competition and Aggregate Returns to Specialization,” 2007. <https://doi.org/10.20955/wp.2007.036>.
- Giroldo, Renato, and Brett Hollenbeck. “Winning Big: Scale and Success in Retail.” *SSRN Electronic Journal*, 2020. <https://doi.org/10.2139/ssrn.3613183>.
- Glynn, Mark. “How Supplier Brand Benefits Affect Retailer’s Willingness to Invest.” Accessed March 25, 2023. <https://www.impgroup.org/uploads/papers/8111.pdf>.
- Goldstein, Robin S., Daniel A. Sumner, and Allie Fafard. “Retail Cannabis Prices in California through Legalization, Regulation and Taxation.” *California Agriculture* 73, no. 3 (2019): 136–45. <https://doi.org/10.3733/ca.2019a0025>.



- Grigolon, Laura, and Frank Verboven. “Nested Logit or Random Coefficients Logit? A Comparison of Alternative Discrete Models of Product Differentiation.” *SSRN Electronic Journal*, 2011. <https://doi.org/10.2139/ssrn.1963117>.
- Hansen, Benjamin, Keaton Miller, and Caroline Weber. “Getting into the Weeds of Tax Invariance,” 2017. <https://doi.org/10.3386/w23632>.
- Hansen, Benjamin, Keaton Miller, and Caroline Weber. “The Taxation of Recreational Marijuana: Evidence from Washington State.” *SSRN Electronic Journal*, 2017. <https://doi.org/10.2139/ssrn.3006807>.
- Hansen, Benjamin, Keaton Miller, and Caroline Weber. “Vertical Integration and Production Inefficiency in the Presence of a Gross Receipts Tax,” 2021. <https://doi.org/10.3386/w28478>.
- Hollenbeck, Brett, and Kosuke Uetake. “Taxation and Market Power in the Legal Marijuana Industry.” *SSRN Electronic Journal*, 2018. <https://doi.org/10.2139/ssrn.3237729>.
- Hollenbeck, Brett. “Cannabis Data.zip.” Dropbox. Accessed March 24, 2023. [https://www.dropbox.com/s/2ths5zgdrgo7xnf/Cannabis%20data.zip?dl=0&file\\_subpath=%2FCannabis%2Bdata](https://www.dropbox.com/s/2ths5zgdrgo7xnf/Cannabis%20data.zip?dl=0&file_subpath=%2FCannabis%2Bdata).
- Ikuta, Yusuke. “Linear Supply Function Competition in a Vertically Related Market.” *International Journal of Economic Policy Studies* 12, no. 1 (2017): 1–22. <https://doi.org/10.1007/bf03405766>.
- Kim, Jaehwan, Greg M. Allenby, and Peter E. Rossi. “Modeling Consumer Demand for Variety.” *Marketing Science* 21, no. 3 (2002): 229–50. <https://doi.org/10.1287/mksc.21.3.229.143>.
- Koga, Maiko, Koichi Yoshino, and Tomoya Sakata. “Strategic Complementarity and Asymmetric Price Setting among Firms.” SSRN, April 17, 2020. <https://ssrn.com/abstract=3576049>.
- Luo, Bowen. “Manufacturer-Retailer Relationships and the Distribution of New Products.” *SSRN Electronic Journal*, 2021. <https://doi.org/10.2139/ssrn.3830596>.
- Luo, Bowen. “Manufacturer-Retailer Relationships and the Distribution of New Products.” *SSRN Electronic Journal*, 2021. <https://doi.org/10.2139/ssrn.3830596>.
- Mahamad, Syed, Elle Wadsworth, Vicki Rynard, Samantha Goodman, and David Hammond. “Availability, Retail Price and Potency of Legal and Illegal Cannabis in Canada after Recreational Cannabis Legalisation.” *Drug and Alcohol Review* 39, no. 4 (2020): 337–46. <https://doi.org/10.1111/dar.13069>.

- Manello, Alessandro, and Giuseppe Calabrese. "The Influence of Reputation on Supplier Selection: An Empirical Study of the European Automotive Industry." *Journal of Purchasing and Supply Management* 25, no. 1 (2019): 69–77. <https://doi.org/10.1016/j.pursup.2018.03.001>.
- McAfee, R. Preston. "Endogenous Availability, Cartels, and Merger in an Equilibrium Price Dispersion." *Journal of Economic Theory* 62, no. 1 (1994): 24–47. <https://doi.org/10.1006/jeth.1994.1002>.
- Morrow, W. Ross, and Steven J. Skerlos. "Fixed-Point Approaches to Computing Bertrand-Nash Equilibrium Prices under Mixed-Logit Demand." *Operations Research* 59, no. 2 (2011): 328–45. <https://doi.org/10.1287/opre.1100.0894>.
- "One Size Fits All? The Value of Standardized Retail Chains." Accessed March 25, 2023. [https://www.web.stanford.edu/~bklopack/JMP\\_draft.pdf](https://www.web.stanford.edu/~bklopack/JMP_draft.pdf).
- Pancras, Joseph, S. Sriram, and V. Kumar. "Empirical Investigation of Retail Expansion and Cannibalization in a Dynamic Environment." *Management Science* 58, no. 11 (2012): 2001–18. <https://doi.org/10.1287/mnsc.1120.1540>.
- Papadamou, Stephanos, Alexandros Koulis, Constantinos Kyriakopoulos, and Athanasios P. Fassas. "Cannabis Stocks Returns: The Role of Liquidity and Investors' Attention via Google Metrics." *International Journal of Financial Studies* 10, no. 1 (2022): 7. <https://doi.org/10.3390/ijfs10010007>.
- "The Power of Trust in Manufacturer-Retailer Relationships." *Harvard Business Review*, August 1, 2014. <https://hbr.org/1996/11/the-power-of-trust-in-manufacturer-retailer-relationships>.
- Qin, Fei, Uday S. Rao, Haresh Gurnani, and Ramesh Bollapragada. "Role of Random Capacity Risk and the Retailer in Decentralized Supply Chains with Competing Suppliers." *Decision Sciences* 45, no. 2 (2014): 255–79. <https://doi.org/10.1111/deci.12067>.
- Rajagopalan, S., and Nan Xia. "Product Variety, Pricing and Differentiation in a Supply Chain." *European Journal of Operational Research* 217, no. 1 (2012): 84–93. <https://doi.org/10.1016/j.ejor.2011.08.016>.
- Rhodes, A. "Multiproduct Retailing." *The Review of Economic Studies* 82, no. 1 (2014): 360–90. <https://doi.org/10.1093/restud/rdu032>.
- "Rule-of-Thumb Pricing: Retail Cannabis in Washington State - WPMU Dev." Accessed March 25, 2023. [https://cpb-us-e1.wpmucdn.com/sites.northwestern.edu/dist/f/2588/files/2018/09/Escudero\\_JMP-2csnvuv.pdf](https://cpb-us-e1.wpmucdn.com/sites.northwestern.edu/dist/f/2588/files/2018/09/Escudero_JMP-2csnvuv.pdf).

- Sarkis, Joseph, and Srinivas Talluri. "A Model for Strategic Supplier Selection." *The Journal of Supply Chain Management* 38, no. 1 (2002): 18–28. <https://doi.org/10.1111/j.1745-493x.2002.tb00117.x>.
- Smith, Howard W., and John E. Thanassoulis. "Upstream Competition and Downstream Buyer Power." SSRN, October 11, 2006. <https://ssrn.com/abstract=936712>.
- Sudhir, K. "Structural Analysis of Manufacturer Pricing in the Presence of a Strategic Retailer." *Marketing Science* 20, no. 3 (2001): 244–64. <https://doi.org/10.1287/mksc.20.3.244.9764>.
- Sudhir, K. "Structural Analysis of Manufacturer Pricing in the Presence of a Strategic Retailer." *Marketing Science* 20, no. 3 (2001): 244–64. <https://doi.org/10.1287/mksc.20.3.244.9764>.
- Tanak Coşkun, Gamze, and Ayten Yılmaz Yalçiner. "Determining the Best Price with Linear Performance Pricing and Checking with Fuzzy Logic." *Computers & Industrial Engineering* 154 (2021): 107150. <https://doi.org/10.1016/j.cie.2021.107150>.
- Thomas, Danna. "License Quotas and the Inefficient Regulation of Sin Goods: Evidence from the Washington Recreational Marijuana Market." *SSRN Electronic Journal*, 2018. <https://doi.org/10.2139/ssrn.3312960>.
- Villas-Boas, Sofia. "Vertical Contracts between Manufacturers and Retailers: An Empirical Analysis." *SSRN Electronic Journal*, 2003. <https://doi.org/10.2139/ssrn.444321>.
- Wilson, Chris M. "Market Frictions: A Unified Model of Search and Switching Costs." *SSRN Electronic Journal*, 2009. <https://doi.org/10.2139/ssrn.1346887>.
- Zhang, Xiaoting. "Trends in Working Capital Management and Its Impact on Firms' Performance – an Analysis of Smes." *Research on Modern Higher Education*, 2017. <https://doi.org/10.24104/rmhe/2017.03.01008>.
- Zhao, Qiu. "The Influence of Buyer Power on Supply Chain Pricing with Downstream Competition." *Sustainability* 11, no. 10 (2019): 2924. <https://doi.org/10.3390/su11102924>.