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The delayed surplus response for hops related to market dynamics

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Abstract: The cyclical nature of hop market pricing has been recorded since the 16th century, but the effect had never previously been documented or quantified. Using Bayesian inference in an analysis of data regarding the US hop industry collected and published by the United States Department of Agriculture (USDA) it was possible to measure the change of inventory and acreage responsiveness to price during periods of free and markets regulated through the enforcement of intellectual property rights (IPR). The data demonstrated a delayed, reduced, or total lack of responsiveness in the change of direction of acreage and inventory in response to directional changes in season average price (SAP) during free market periods. This reaction was referred to as the delayed surplus response (DSR). The data also demonstrated the absence of the DSR during periods in which proprietary varieties reached greater than 50% of US acreage and production. Patented plant varieties offer a legal monopoly over that intellectual property (IP). The absence of the DSR during periods in which a majority of US acreage and production were proprietary indicated a strong degree of control over supply. By extension, the owners of proprietary varieties demonstrated the ability to influence price at desired levels.

Keywords: Bayesian inference; brewing industry; disequilibrium; hop market; proprietary variety

Hops (*Humulus lupulus* L.) are a perennial that grow bines requiring a trellis system capable of supporting the weight of the vines themselves as well as the many cones each bine may produce. Commercial production takes place in latitudes greater than 35 degrees in both the Northern and Southern Hemispheres due to strong photoperiodism requirements for flowering (Henning et al. 2015). In the US in 2021 we noted 41% of the global hop production with the average hop yield of 2.1 metric tons per hectare. This weight represented only the cones, not the weight of the bines themselves.

Breweries are the primary customer requiring hops in significant quantities and are responsible for 98% of global hop sales. The demand for other products, therefore, does not affect the hop market in a meaningful way. The hop industry is relatively small. Therefore hops are not publicly traded. Instead, they are traded in what is referred to as over-the-counter (OTC) deals. The practice of OTC trading is an archaic, yet effective, system requiring personal communications between the interested parties, but lacks transparency. The hop industry is therefore an opaque market oscillating between the influences of a merchant oligopoly and a brewer oligopsony depending upon the supply situation.

Folwell et al. (1985) first introduced the concept of a 'lagged supply response' when describing the hop market disequilibrium. That term however does not ad-

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equately describe the situation. Supply is highly elastic and responsive to increasing prices. It is the industry's response to declining demand that is lagging leading to the term 'delayed surplus response' (DSR).

The United States Department of Agriculture (USDA) practice of aggregating US hop industry data for over 100 years in a consistent way that protects grower confidentiality, and on a regular schedule removes any potential data biases making it suitable for a Bayesian analysis (Bayarri and Berger 2004). USDA season average price (SAP) acreage and production data demonstrated that in response to deficit situations in 1980, 2007 and 2008, US grower responses were rapid.

MATERIAL AND METHODS

Calculating the depletion rate

The US hop stock figures represented inventory in warehouses located in the US. To achieve a more accurate picture of the amount of the US and foreign hops stored in the US during the period analysed, import and export figures were added to the equation.

The depletion rate is the rate of change from one data point to the next similar data point. We measured the depletion rate between annual September 1 hop stocks figures. Alternate depletion rates (i.e. between September year $n-1$ and March year n or between March year $n-1$ and March year n) may be calculated and provide some value. For the purposes of this research, however, the September 1 depletion rate was used and will be referred to henceforth as 'the depletion rate'.

We calculated the depletion rate by taking the September 1 US hop stocks value for the previous year $n-1$, $\sqrt{(S^{n-1})}$ adding in the total production of the US crop (accounting for processing loss) for year $n-1$, $\sqrt{(C'^{n-1})}$, and subtracted the September 1 US hop stocks value for year n, $\sqrt{(S^{n})}$. To account for the quantity of hop production lost during processing for any year n into pellets or extract, referred to as $\sqrt{(C'^{n})}$, we estimated that 97% of the original raw production volume (hops in bale form). Furthermore, we estimated that 3% of the crop remained in bale form. For these hops, it can be assumed there was zero loss. These conversion rates came from a priori knowledge and will certainly change in the future as brewer purchasing preferences change. These numbers may be adjusted as necessary to test an alternate set of beliefs. The formula below represents this calculation.

$$D^{n} = S^{n} - \left[\left(S^{n-1} + C'^{n-1}\right) - S^{n}\right] \quad (1)$$

where: D^n – depletion rate; S^n – September 1 hop stocks figures for year n; S^{n-1} – September 1 hop stocks figures for year $n-1$; C'^{n-1} – total production of the US crop once processing loss has been accounted for.

Data populations

For this research, we analysed USDA SAP, September 1 hop stocks and acreage for two data subpopulations.

1980–2000. The years 1980 to 2000 were marked by a lack of effective regulation over a supply and the introduction of new hop varieties and products with greater efficiency. This was a time when four situations converged and created a surplus market situation:

i) The third Federal Marketing Order had failed because as Folwell (1982) mentioned growers increased saleable quantities to take market share away from German growers (creating a permanent infrastructure production solution in the US to a temporary German yield problem).

ii) The new high-yielding alpha varieties, Nugget and Galena, were introduced to the market replacing lower-yielding alpha producing hops on a 1 : 1 basis increasing grower production efficiency of alpha acid per acre.

iii) Merchant proprietary products based on alpha acid with greatly increased efficiencies were introduced to the market reducing demand by brewers. There were no effective forms of production or sales regulation during this period.

iv) Early proprietary alpha hop varieties were quietly introduced into the market under other variety names (i.e. red stripe Nugget). It is not possible to quantify the scale of this effect as the new acreage was reported as Nugget and there was no way to distinguish actual Nugget acreage from 'red stripe' Nugget acreage [which many later speculated was one of the Columbus, Tomahawk and Zeus (CTZ) varieties].

1998–2020. This was a period during which branded proprietary varieties were introduced into the market. It was also a time during which the craft brewing industry reached a tipping point enabling its demands for proprietary aroma varieties for which they were willing to pay a premium to direct the industry. Since 1938, the US hop industry had experimented with Federal Marketing Orders to regulate the saleable quantity of hops to brewers. All three Federal Marketing Orders that were enacted failed due to the lack of authority to effectively regulate grower activities. A fourth Federal Marketing Order was voted down in 2003 with concerns over the potential for the formation of a cartel expressed by one significant opponent. Proprietary variety pro-

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duction, however, grew to such an extent that it effectively created the regulatory system the industry had long sought via the enforcement of intellectual property rights (IPR). Correlation however does not imply causation. The reverse, however, is not true. Causation implies some form of correlation (Goldthorpe 2001).

Bayesian inference

For each data set, we analysed the effect of a hypothetical change in the independent variable upon the directional movement of the dependent variable (i.e. increase, decrease, no change) while keeping other variables stable (Hines 2015). We measured the effect of consecutive hypothetical identical changes to the independent variable upon the dependent variable to determine the probability of a change occurring because of the change.

Limiting the possible numbers of outcomes increased the ability of our Bayesian inferential analysis to yield meaningful probability forecasts. A simple model can increase the chance for accuracy and reduce errors in forecasting by as much as 25% (Green and Armstrong 2015). The parameters of this analysis were limited to the directional movement of dependent and independent variables to limit false discovery data. More accurate probabilities resulted without compromising the integrity of the operation. Yekutieli (2012) concluded that while specifying a selection rule introduces an arbitrary element to Bayesian analysis, the selection rule was determined before the data were observed and carried out the same way as Bayesian inference. Our inferences were based on the Bayesian posteriors generated from a selection-adjusted analysis, which as Yekutieli (2012) noted led to a reduction in the forecasts possible from the available data (i.e. forecasts regarding directional price movements as opposed to forecasts regarding the probability of actual future prices).

The Bayesian formula

$$P(A|B) = \frac{P(B|A)}{P(B)} P(A) \tag{2}$$

where: $P(A|B)$ – probability of A occurring given that B was true; $P(B|A)$ – probability of B occurring given that A was true; $P(B)$ – probability of observing B; $P(A)$ – probability of observing A; A, B – unique events.

RESULTS AND DISCUSSION

The Bayesian inferential of analyses of the US SAP resulted in the emergence of several sequences of data demonstrating that September 1 hop stocks and acreage did not follow market signals indicating reduced demand for hops. We discovered that when US SAP decreased two years in a row during the period 1980–2000 it resulted in a 100.00% likelihood that September 1 hop stocks would increase, a trend that continued through the fourth consecutive year of US SAP decreases (Table 1).

The data reflected that these two factors impacted market forces. There was only a slight reaction in the *n* year to a decrease in US SAP. The prior probability of an increase in stocks of 38.10% changed to a posterior probability of 41.67%, a mild change. In the second consecutive year and beyond the posterior probabilities were 100.00%. The same was true of the sensitivity

Table 1. US SAP decreased in consecutive years and the probability of an increase in US September 1 hop stocks (1980–2000) (%)

Description	Prior probability	Posterior probability	PPV	Sensitivity	Specificity
US SAP year *n* decreased; US September 1 stocks increase	38.10	41.67	62.50	41.67	62.50
US SAP year *n* decreased 2 consecutive years; US September 1 stocks increase	41.67	100.00	61.54	100.00	0.00
US SAP year *n* decreased 3 consecutive years; US September 1 stocks increase	100.00	100.00	64.29	100.00	0.00
US SAP year *n* decreased 4 consecutive years; US September 1 stocks increase	100.00	100.00	66.67	100.00	0.00

PPV – positive predictive values; SAP – season average price
Source: USDA NASS (2013, 2014, 2020)

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demonstrating the certainty of the true positive (TP) results. The positive predictive values (PPV) introduced some room for doubt, but only marginally. The *n*-year PPV was 62.50% and increased by the fourth consecutive year to a mere 66.67%.

Similar changes during the 1998–2020 period yielded very different results with very low probabilities of increases in September 1 hop stocks in years two, three and four of the calculations (Table 2). Following consecutive years of decreased US SAP, the posterior probability (i.e. the likelihood) that stocks will increase resulting from these changes decreased to 21.69% by the fourth consecutive year of decreased US SAP. The PPV was high in the *n* year at 90.00%. This demonstrated a high degree of confidence in the posterior probability generated in that year. The PPV decreased during the second, third and fourth consecutive years of decreasing US SAP. By the fourth consecutive decrease in US SAP, the PPV was 60.00%. This is considered by our research to be a high value, but in conjunction with the direction of its movement provided by the other years measured in this research, we could better understand its relative significance.

There exists a symbiotic relationship between acreage, production and stocks. Experiments regarding US SAP data and its effect upon US acreage yielded data that demonstrated that acreage lacked responsiveness to price signals indicating reduced demand during the 1980–2000 period (Table 3). There was a low probability of a decrease in acreage in response to consecutively decreasing prices. The year *n* posterior probability of a 37.50% likelihood of such a decrease increased to 50.00% by the fourth year of consecutive decreased US SAP.

The low PPV of 33.33% in the *n* year increasing only to 50.00% in the fourth consecutive year of US SAP decreases instilled confidence in the ability to forecast accurately using these results. These data are a result of the following events that occurred:

i) The newly introduced high-yielding alpha varieties of Nugget and Galena created a Bertrand Supertrap reducing demand for US hop acreage as efficiency was greatly increased on the farm.

ii) The introduction of a proprietary processed alpha-oriented products added to the effects of the Bertrand Supertrap. The hyper efficiency of these new products further reduced the demand for alpha hop products by brewers and the need for existing hop acreage.

iii) The complete lack of effective regulation of production or saleable quantities, acreage and production, meaning that laissez-faire economics were governing the market, which was in essence a free for all.

iv) The homogeneity of hop products marketed between 1980 and 2000.

All of these led to circumstances in which growers could not compete on price alone. Even some branded proprietary varieties that existed at the time (i.e. a proprietary variety referred to as Red Stripe Nuggets so it could be sold as a Nugget when it was not) found their way into the homogenous product stream offering a disproportionate advantage to the morally impaired growers who did not shy away from selling an intentionally mislabeled product.

The data from the 1998–2020 period demonstrated that the opposite was true during that time, which indicated a greater likelihood of responsiveness to market price signals (Table 4). The data during the period between

Table 2. US SAP decreased in consecutive years and the probability of an increase in US September 1 hop stocks (1998–2020) (%)

Description	Prior probability	Posterior probability	PPV	Sensitivity	Specificity
US SAP year *n* decreased; US September 1 stocks increase	43.48	60.00	90.00	60.00	85.71
US SAP year *n* decreased 2 consecutive years; US September 1 stocks increase	60.00	44.68	53.85	87.50	0.00
US SAP year *n* decreased 3 consecutive years; US September 1 stocks increase	44.68	31.58	57.14	88.89	0.00
US SAP year *n* decreased 4 consecutive years; US September 1 stocks increase	31.58	21.69	60.00	90.00	0.00

PPV – positive predictive values; SAP – season average price
Source: USDA NASS (2013, 2014, 2020)

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Table 3. US SAP decreased in consecutive years and the probability of US acreage decreases (1980–2000) (%)

Description	Prior probability	Posterior probability	PPV	Sensitivity	Specificity
US SAP year *n* decreased; US acreage decrease	42.86	37.50	33.33	37.50	50.00
US SAP year *n* decreased 2 consecutive years; US acreage decrease	37.50	36.55	40.00	44.44	50.00
US SAP year *n* decreased 3 consecutive years; US acreage decrease	36.55	38.59	45.45	50.00	50.00
US SAP year *n* decreased 4 consecutive years; US acreage decrease	38.59	42.99	50.00	54.55	50.00

PPV – positive predictive values; SAP – season average price
Source: USDA NASS (2013, 2014, 2020)

1998 and 2020 suggested high responsiveness to consecutive decreased US SAP. Such strong data were not evidenced during the other data subpopulations measured with respect to US SAP and US acreage. In year *n*, in response to a single decrease of US SAP the probability of acreage decreasing increased from the prior probability of 43.48% to a posterior probability of 71.43%. After another year of decreased US SAP, the posterior probability representing the likelihood of an acreage decrease jumped to 89.86%. In the third and fourth consecutive years, the likelihood soared yet again to 97.11% and 99.26% probability. These data represented not only a high degree of correlation but causation between the two data points under these circumstances.

The PPV remains strong with values going from 50.00% in the *n* year to 61.54% in the fourth consecutive year introducing reasonable doubt into the equation in what otherwise appeared to be near certainty with regards to acreage reduction. The high degree of sensitivity in these data with values ranging from 71.43% in the *n* year and increasing to 80.00% in the fourth consecutive year was of interest in that it suggested a high TP rate.

These results were significant. They represented the first occurrence of a situation in which we can see that the DSR effect was not present indicating that something has changed with regards to how the market operates. There was an increased degree of control making acreage more responsive to market forces.

It is reasonable to assume that an individual or entity that owns a patent would act in his or her best financial interest. At a minimum, we may assume such individuals would certainly not act in a way contrary to their interests. The individuals that owned the entities responsible for developing proprietary varieties that comprised 70% of US acreage in 2020 also either owned or were involved in hop farming or hop merchant entities. Data demonstrated that the supply of proprietary

Table 4. US SAP decreased in consecutive years and the probability of US acreage decreases (1998–2020) (%)

Description	Prior probability	Posterior probability	PPV	Sensitivity	Specificity
US SAP year *n* decreased; US acreage decrease	43.48	71.43	50.00	71.43	68.75
US SAP year *n* decreased 2 consecutive years; US acreage decrease	71.43	89.86	54.55	75.00	68.75
US SAP year *n* decreased 3 consecutive years; US acreage decrease	89.86	97.11	58.33	77.78	68.75
US SAP year *n* decreased 4 consecutive years; US acreage decrease	97.11	99.26	61.54	80.00	68.75

PPV – positive predictive values; SAP – season average price
Source: USDA NASS (2013, 2014, 2020)

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products has been managed in such a way as to discourage overproduction. Hop surpluses following periods of deficit historically decreased prices due to the inelastic demand for hops. Increased responsiveness of acreage and stocks to price signals indicating decreasing demand occurred during the 1998–2020 period.

CONCLUSION

The period 1980–2000 contained data that represented surging stock levels and what we have referred to as the DSR. Stock levels were among the underlying market characteristics that affected price volatility. Data suggest the disequilibrium created by the DSR has been responsible for market imbalances and the boom-and--bust cycles recorded in the hop industry. The increase in the concentration of power within the hop industry changes market dynamics. SAP data strong merchant oligopoly during times of deficit to a strong brewer oligopsony during times of surplus combined with forced contracting that is later renegotiated respectively contributes to the DSR. Reduced contract revenue following renegotiation and/or reneging resulting from decreased prices enables lower profits than would otherwise be possible on the spot market without the presence of contracts (Cabral and Villas-Boas 2005).

The period 1998–2020 produced data that demonstrated the absence of the DSR during that time representing a significant change in market dynamics. One of the primary differences between the 1980–2000 and 1998–2020 periods was the ability to effectively regulate the production and saleable quantity of proprietary hop varieties using IPR. Intellectual property (IP)-related constraints to the market affected planting decisions (Stiglitz and Dixit 1977). Patented varieties represent the potential for legal monopoly control over a product. IPR empower individuals to regulate acreage, production, and therefore stocks of the varieties they own.

The DSR represented the natural dynamics of the hop market for centuries. The high concentration of proprietary hop varieties in the US industry altered those dynamics. It is still unknown whether their presence has completely removed the DSR or created an extended DSR that will reveal itself over a longer period. The authors speculate the latter will be the case, but further research in the future will be necessary to confirm this.

REFERENCES

Bayarri M.J., Berger J.O. (2004): The interplay of Bayesian and frequentist analysis. Statistical Science, 19: 58–80.

Cabral L.M., Villas-Boas M. (2005): Bertrand supertraps. Management Science, 51: 559–613.

Folwell R.J. (1982): The U.S. Hop Marketing Order: The Price of Success is Misunderstanding. Washington State University, Pullman. Department of Agricultural Economics. Accessed as part of Exhibit 28 of the 2003 USDA Federal Hop Marketing Order hearing records via email with USDA Agricultural Marketing Service (AMS) personnel on May 7, 2019.

Folwell R.J., Mittelhammer R.C., Hoff F.L., Hennessy P.K. (1985): The Federal Hop Marketing Order and volume--control behavior. Agricultural Economics Research, 37: 17–32.

Goldthorpe J. (2001): Causation, statistics and sociology. European Sociological Review, 17: 1–20.

Green K., Armstrong J. (2015): Simple *versus* complex forecasting: The evidence. Journal of Business Research, 68: 1678–1685.

Henning J.A., Gent D.H., Twomey M.C., Townsend M.S., Pitra N.J., Matthews P.D. (2015): Precision QTL mapping of downy mildew resistance in hop (*Humulus lupulus* L.). Euphytica, 202: 487–498.

Hines K. (2015): A primer on Bayesian inference for biophysical systems. Biophysical Journal, 108: 2103–2113.

Stiglitz J.E., Dixit A.K. (1977): Monopolistic competition and optimum product diversity. The American Economic Review, 67: 297–308.

USDA NASS (2013): WA Hops 1915–2013. United States Department of Agriculture National Agricultural Statistics Service (USDA NASS). Available at https://www.nass.usda.gov/Statistics_by_State/Washington/Publications/Historic_Data/index.php#hops (accessed July 18, 2022).

USDA NASS (2014): Hop Stocks Held by Growers, Dealers, and Brewers, United States (1,000 Pounds). United States Department of Agriculture National Agricultural Statistics Service (USDA NASS). Available at https://www.nass.usda.gov/Statistics_by_State/Washington/Publications/Historic_Data/index.php#hops (accessed July 18, 2022).

USDA NASS (2020): National Hop Reports (NHR) for Years 2000–2020. [Dataset]. United States Department of Agriculture National Agricultural Statistics Service (USDA NASS). Available at https://www.nass.usda.gov/Statistics_by_State/Washington/Publications/Hops/index.php (accessed July 18, 2022).

Yekutieli D. (2012): Adjusted Bayesian inference for selected parameters. Journal of the Royal Statistical Society, 74: 515–541.

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