PRICE DYNAMICS IN THE MARKET OF HOPS

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Abstract

This research measures the correlation between season average prices for hops with hop stocks and hop hectarage. The Hop Equilibrium Ratio, a measure of the supply/demand relationship for U.S. hops, was introduced. Through the Bayesian inference method, the authors used these data to calculate the effect of an incremental change to one metric had on the probability of directional changes of future U.S. season average prices (SAP). Between 2010 and 2020, the dominance of trademarked and patented varieties created unique powers for supply and price management. Research results enable more accurate price forecasting in the hop industry.

Keywords: hop market, alpha-acids, brewing industry, Bayesian theorem, equilibrium, economies of scale

DINAMIKA CEN NA TRGU S HMELJEM

Izvleček

V raziskavi merimo korelacijo med sezonskimi povprečnimi cenami hmelja, zalogami hmelja in površinami hmeljišč. Uvajamo merilo razmerja med ponudbo in povpraševanjem - ravnotežno razmerje hmelja. S pomočjo Bayesovega sklepanja avtorja te podatke uporabita za izračun učinka, ki ga ima postopna sprememba ene statistike na verjetnost sprememb prihodnjih sezonskih povprečnih cen hmelja v ZDA. Med letoma 2010 in 2020 je prevlada blagovnih znamk in patentiranih sort ustvarila edinstvene možnosti za upravljanje ponudbe in cen. Rezultati raziskave omogočajo natančnejšo oceno gibanja cen hmelja.

Ključne besede: trg hmelja, alfa-kisline, pivovarstvo, Bayesov izrek, ravnovesje, ekonomija obsega

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1　　　INTRODUCTION

Without hops, beer cannot be made, causing on a market its inelastic demand. Breweries consume 98% of global hop production (Cooberg and Hintermeier, 2012). Small volumes of hops can bitter, preserve and flavor large volumes of beer meaning the market can quickly fall into disequilibrium. Substitutability between competing hop varieties produced solely for their high alpha-acid contents creates cross elasticity between producer groups, the largest of which were the U.S. and Germany in 2019 (George, 2019). In 2018, the U.S. hop industry represented 48.3% of the global alpha acid supply (BarthHaas, 1948-2019).

Large buyers use their bargaining power to lower input prices (OECD, 2012). The world's largest brewing conglomerates (big brewers) consolidated during the 20th century. The ten largest controlled 72.5% of beer production by 1981 (BarthHaas, 1948-2019). This created an oligopsonistic dynamic between brewers and hop merchants. Big brewers used their influence to get favorable pricing. Pricing under an oligopsony, however, does not behave the same as under free market competition. Prices can increase as supply increases (Chen and Lent, 1992). Hop merchants often match a competitor's price via tacit collusion to retain or capture market share in a zero-sum game. A Nash equilibrium of the Bertrand model often prevailed as competition was primarily price based (Hermalin, 2003).

With the development of higher-yielding hop varieties in the 1980's and 1990's, merchants differentiated themselves through lines of proprietary processed products. These new products provided a temporary advantage to the innovator while creating a Bertrand Supertrap (Cabral and Villas-Boas, 2005) as they decreased the size of the overall market.

Prior to the shortage of 2007, increases in SAP began as early as 2004. An accurate forecasting model to measure the disequilibrium could have prevented the 2007 shortage, which cost brewers hundreds of millions of dollars. SAP increased 45% in a single year (NHR, 2019). The volume of forward contracts in 2009 (IHGC, 2009) was 65% greater than in 2005 (IHGC, 2005). By 2010, the production of privately owned patented and branded varieties expanded rapidly. Constrained Pareto optimality led to the counterintuitive expansion of varieties with greater inelasticity while more elastic varieties were restricted (Stiglitz et al., 1977). U.S. production increased 15 603 MT (57%). A global surplus of alpha-acids developed (BarthHaas, 1948-2019). By 2012, many contracts had been renegotiated. SAP decreased 30% from its 2008 high while production returned to 2007 levels (NHR, 2019).

Empirical evidence between 2010 and 2012 suggested American craft brewers wanted a closer working relationship with their suppliers and would pay premium prices, unlike the big brewers. Craft brewers represented an opportunity to

circumvent the big brewer oligopsony. Non-price competition between branded proprietary varieties exploded in response to soaring demand by craft brewers between 2010-2016 (NHR, 2019). Between 2011 and 2019, American hop acreage increased 97.8% (George, 2019).

In the most extreme cases, craft brewers used even 500-700 times more hops per hectoliter than the big brewers. The growing size of the maturing segment combined with the premium prices they paid granted them a disproportionate influence on the market. The number of craft breweries in the U.S. surged from 1,813 in 2010 to nearly 8,000 in 2019 (Brewers Association, 2020). Their effect on global hop usage was significant (BarthHaas, 1948-2019; MacKinnon and Pavlovič, 2021). The craft revolution, as it became known, was led in the U.S. by rapidly increasing demand for India Pale Ales (IPAs) (Watson, 2015). The rapid reorientation toward proprietary hop varieties between 2010 and 2019 represented efforts by growers and craft brewers to differentiate themselves from their competitors (MacKinnon and Pavlovič, 2019). Production of proprietary hop varieties rose from zero in 1997 to 66% of the 51,256 MT produced in the U.S. in 2019 (NHR, 2019). These were primarily the Intellectual Property (IP) of six entities. The demand for new varieties created incentives for private breeders to invest in innovation, because they could define it and thus seek to protect and enforce their rights in it (Bugos and Kevles, 1992). IP facilitated cartel-like power among a very few the Federal Marketing Orders (FMOs) of the previous generation could never have offered. The presence of IP constrained the market in new ways, which affected planting decisions (Stiglitz et al., 1977). Rather than restrict growth of proprietary varieties to their farms, IP owners license 3rd party farms as production units. They controlled production, marketing, and in some cases, retained ownership of the plant material produced. Between 2000 and 2019, proprietary varieties, each of which enjoyed a monopoly, became a vector for regulating production and saleable quantities. Prices soared.

Like other commodities, hops have significant seasonailities and require a far more elaborate time-series specification of the price dynamics of the underlying asset (Foster and Whiteman, 1999). A useful model would be designed to allow for subjective judgment according to Cromarty and Meyers (1975). A statistical forecasting approach that could be implemented in concert with a priori knowledge would create a more thorough understanding of hop market dynamics. The goal of this research was to quantify for the first time the relationship between different publicly available statistics and determine which could be used in building such a model.

2   MATERIAL AND METHODS

We referenced annual season average price, production and acreage data for the U.S. market converted into hectarage (USDA NASS, 2013). For other production regions,

we referred to annual BarthHaas Reports (BarthHaas, 1948-2019) and International Hop Growers Convention (IHGC) economic committee reports (IHGC, 2005; IHGC, 2009).

To analyze the effects of change on the change in raw prices from year to year, we used SAP data unadjusted for inflation from 1948-2019. We analyzed three sets of data: (i) the total data set, 1948-2019, (ii) the subset of 1980-2019, a period after which the third FMO was dysfunctional and (iii) the subset of 2000-2019, the period documenting the rise of proprietary varieties in the U.S.

2.1   Bayesian analysis

We used Bayes' theorem and Bayesian inference to calculate probabilities due to the accuracy of the test and the richness of the data provided. We applied the theorem to industry data in 266 Bayesian analyses. Season average price was used as both the dependent and independent variable resulting in 25,802 calculations using Microsoft® Excel for Mac version 16.42. Each analysis contained three unique independent variables and three unique dependent variables through a series of calculations including prior, conditional, joint, marginal and posterior probability values for each set of circumstances measured. Ultimately, a Bayesian hierarchical modeling offers the opportunity to combine estimates based on historical data together with information gathered via ex ante methods and weight them based on their perceived importance (Cabrini et al., 2010).

$$P(A|B) = \frac{P(B|A)}{P(B)} P(A) \qquad (1)$$

Where P(A|B) is the probability of A occurring given that B is true
Where P(B|A) is the probability of B occurring given that A is true
Where P(B) is the probability of observing B
Where P(A) is the probability of observing A
Where A and B are unique events

For example:

Probability (SAP Increase | Increase in Sept. 1 Stocks)

$$= \frac{\text{Probability (Increase in Sept. 1 Stocks | SAP Increase)}}{\text{Probability (Increase in Sept.1 Stocks)}} \text{ Probability (SAP Increase)} \quad (2)$$

We used the Bayesian inference method to calculate the probabilities of directional changes in our dependent variable for possible future years based on consecutive identical changes to our independent variable. We focused on SAP in the role of both

dependent and independent variable and measured identical changes to dependent variables after two, three and four years of successive identical changes.

2.2 Hop Equilibrium Ratio

We created the Hop Equilibrium Ratio (HER) to measure the appropriateness of the supply from year n relative to the demand in year n+1, a measurement previously lacking. The HER yielded the distance from market equilibrium in percent, from which an aggregate surplus or deficit could be calculated. The ratio may be used as an early indicator of the effects of demand on the price of years *n* and *n+1*.

The HER for any given year n is as follows, where D is the depletion rate and C´ represents the volume of the crop produced post processing:

$$HER^n = \frac{D^n}{C'^{n-1}} \tag{3}$$

To achieve this, we calculated the depletion rate of U.S. inventory by taking the September U.S. hop stocks value for the previous year n-1, (S^{n-1}) adding in the total production of the U.S. crop (accounting for processing loss) for year n-1, (C'^{n-1}), and finally subtracting the September U.S. hop stocks value for year n, (S^n).

$$D^n = S^{n-1} + C'^{n-1} - S^n \tag{4}$$

To account for the quantity of hop production lost during processing for any given year n, referred to herein as (C'^n), we estimated three percent of the crop remained in bale form for which we assumed no loss. We estimated 97% of hops produced were processed into pellets and experienced a three percent loss during processing. These assumptions may be adjusted as necessary to test an alternate set of beliefs. Because we did not feel comfortable assuming a similar ratio of processed hops to raw hops prior to 1979 due to the change in varietal characteristics at that time, we calculated the HER from 1979-2019. We did not add any additional loss for processing pellets into extract or downstream products as we believed those calculations would not materially affect the results. The formula we used for calculating the crop available post processing was as follows:

$$C'^n = ((C^n * 0.97) * 0.97) + (C^n * 0.03) \tag{5}$$

When we calculated the HER for each year using the data from 1948-2019, we observed that the HER value of 0.98 yielded the highest probability of accurate results when forecasting the direction of future pricing.

3   RESULTS AND DISCUSSION

We calculated the probability of a positive, negative, or zero change, in our dependent hop industry variables such as U.S. Stocks, U.S. hectarage and U.S. Hop Equilibrium Ratio (HER) following a positive, negative or zero change of the independent variable, U.S. Season Average Price. We determined results to be significant if a change in the independent variable yielded a change to the posterior probability of the dependent variable by 10% or more in a single year, or if a multi-year series of identical changes lead to a change of 25-30% of the posterior probability relative to the original prior probability of year *n*. As part of the Bayesian process, our calculations also yielded the probability of the correctness of the test result. We omitted results regardless of the apparent significance of the posterior probability if the probability of a correct test result was 60% or less. Twelve situations met these criteria and were worthy of greater attention as research results (Table 1).

Table 1. Significant probabilities of variable changes and trends 1948-2019.

DESCRIPTION	Prior Probability of Change	Posterior Probability of Change	Probability of Correct Result
Stocks* year n decrease, SAP increase	0.6479	0.8077	0.8077
Stocks decreases 2 years, SAP increase	0.8077	0.9004	0.8148
Stocks decreases 3 years, SAP increase	0.9004	0.9522	0.8214
Stocks decreases 4 years, SAP increase	0.9522	0.9782	0.8276
HER year n > 0.98, SAP increases year n	0.6571	0.8261	0.8261
HER > 0.98 for 2 years, SAP increases year n	0.8261	0.9238	0.8333
HER > 0.98 for 3 years, SAP increases year n	0.9238	0.9695	0.8400
HER > 0.98 for 4 years, SAP increases year n	0.9695	0.9885	0.8462
SAP year n increase, hectarage increase	0.5352	0.6304	0.6304
SAP increases 2 years, hectarage increase	0.6304	0.7181	0.6383
SAP increases 3 years, hectarage increase	0.7181	0.7931	0.6458
SAP increases 4 years, hectarage increase	0.7931	0.8531	0.6531

*All Stock figures refer to September 1 hop stocks reported by the USDA NASS; data pertains to the U.S. only unless otherwise mentioned; HER - Hop Equilibrium Ratio; SAP - Season Average Price.
Source: Own study results based on USDA NASS (2013, 2014)

3.1   Correlation between U.S. September 1 Hop Stocks and U.S. SAP

The increase in September 1 U.S. hop stocks represents the amount of hops produced and waiting in reserve for breweries. The increase or decrease of the stocks number must be analyzed in concert with production figures, export numbers, the HER and other factors to paint a more complete picture of the appropriateness of the supply situation.

When we use stocks as the independent variable and SAP as the dependent variable, the results demonstrated the strength of the positive correlation (Table 1). When stocks decreased one year, the probability of a decrease in SAP rose from 64.79% to 80.77%. After two, three and four consecutive years of price decreases, the probability of SAP decreasing was 90.04%, 95.22% and 97.82% respectively. The probability of these results being correct was 80.77% for year one, 81.48% for year two, 82.14% for year three, and 82.76% for year four (Figure 1).

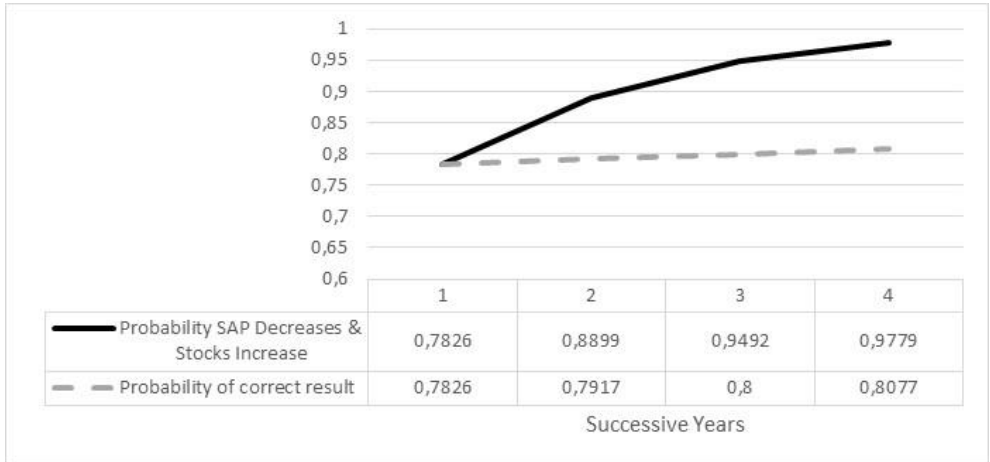|	1	2	3	4
Probability SAP Decreases & Stocks Increase	0,7826	0,8899	0,9492	0,9779
Probability of correct result	0,7826	0,7917	0,8	0,8077

Figure 1: Probability SAP decreases after successive Sept. 1 U.S. stock increase and the probability of correct test results for each period based on 1948-2019 data. Source: Own research

The significance of the correlation between U.S. September 1 stocks and SAP cannot be understated. It is the only known statistic that provides clues to the appropriateness of the supply situation, which, due to the inelastic demand for hops, affects price and the supply situations of foreign countries.

3.2   Correlation between U.S. Hop Equilibrium Ratio and U.S. SAP

In Table 1, the HER for year n, our independent variable, demonstrated a value greater than 0.98 in year n. The probability of an increase in SAP in year n+1, our dependent variable, changed from 66.67% to 77.78% in year one. With two, three and four consecutive years of HER displaying a value greater than 0.98, the probability SAP increases were 86.53%, 92.49% and 96.09% respectively. The probability of these results being correct was 77.78% for year one, 78.95% for year two, 80.00% for year three, and 80.95% for year four (Figure 2).

The HER provides a method for evaluating the appropriateness of the supply from year n for year n+1, the year for which it was produced, which has a subsequent effect on price.

Decreases in SAP resulted in the probability of increased stocks from 61.43% to 78.26% in the first year alone. Following consecutive years of decreasing SAP, the probability increased further. This signals that SAP had a counterintuitive inverse relationship to stock levels (i.e., when prices are higher, customers take delivery of more product). This is evidence of the lagged supply response in the wake of a price spike. The lag quantifies the degree to which breweries over contract for product and is responsible for a perpetual state of disequilibrium.

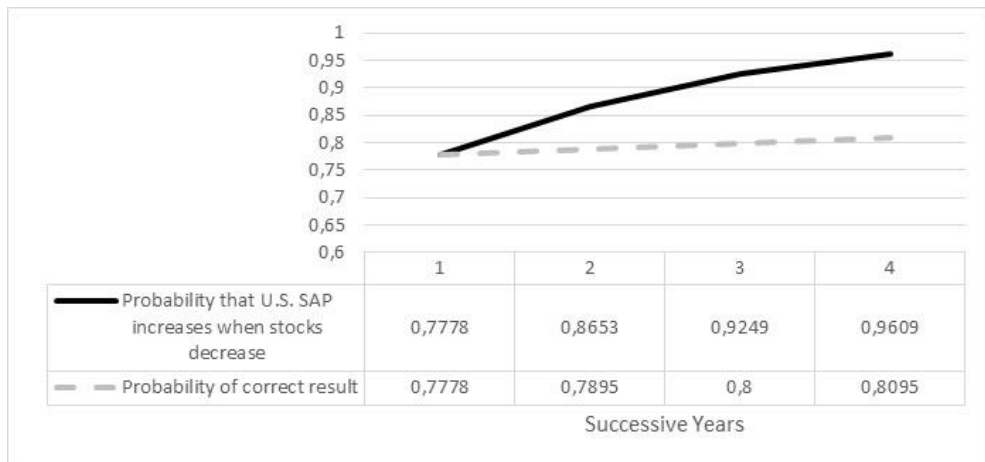|	1	2	3	4
Probability that U.S. SAP increases when stocks decrease	0,7778	0,8653	0,9249	0,9609
Probability of correct result	0,7778	0,7895	0,8	0,8095

Figure 2: Probability U.S. SAP increases after successive U.S. HER values > 0.98 and the probability of correct test results for each period based on 1948-2019 data. Source: Own research

Forecasting directional changes of price movements one year in advance is possible with a high degree of confidence by measuring the balance of the U.S. hop production of year n relative to demand for hops in the U.S. in year n+1. Using the HER value of 0.98 revealed a method to measure annual surpluses and deficits.

3.3   Correlation between U.S. Hectarage and U.S. SAP

In Table 1, the SAP for year n, in this case our independent variable, increased. The probability of U.S. hectarage increasing changed from 53.52% to 63.04% in year one. With two, three and four consecutive years of price increases, the probability of U.S. hectarage increased to 71.81%, 79.31% and 85.31% respectively. The

probability of these results being correct was 63.04% for year one, 63.83% for year two, 64.58% for year three, and 65.31% for year four (Figure 3).
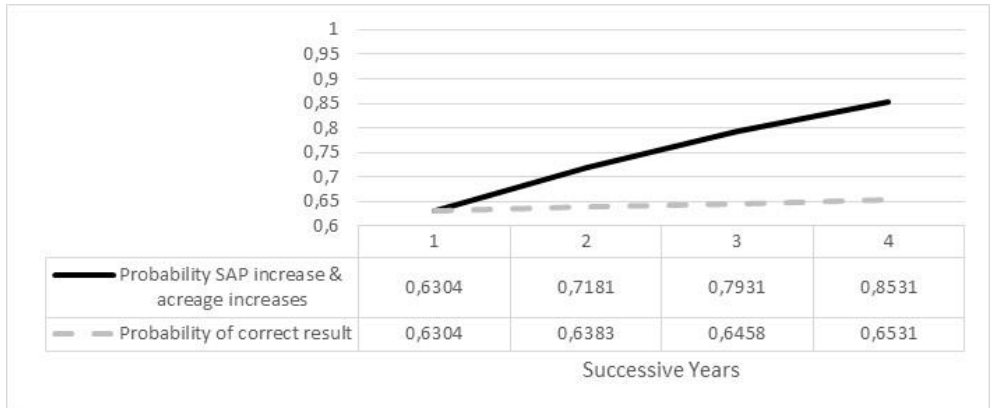

Figure 3: *Probability U.S. hectares increases after successive increases of SAP and the probability of correct test results for each period based on 1948-2019 data. Source: Own research*

There was a weaker relationship between SAP and U.S. hectarage. We assessed it was worth highlighting due to the counterintuitive nature of the trend, where supply and price are both moving together in unison. This happened for two reasons (i) small increases in season average price corresponded with increases in hectarage prior to a price spike that were insufficient to satisfy any existing deficit led to a situation where price and planting were increasing prior to and during price spikes caused by large deficits or shortages, and (ii) SAP and hectarage behaved differently after price spikes due to the macro buyer oligopsony, the over contracting going into a deficit and their ability to renegotiate contracts following the markets subsequent decline once a surplus has developed. This led to falling prices as the production area was decreasing during surplus times.

4   CONCLUSIONS

Publicly available statistical hop data provide sufficient information to forecast future directional movements of hops prices, the threat of upcoming shortages and the scale of surpluses. The ability to accurately track hop inventory will enable an observer to determine the degree of disequilibrium in the market, to anticipate shortages and foresee price spikes. The lack of such a forecasting model in the past has cost the brewing industry and hop producers hundreds of millions of dollars during the past 20 years alone.

Several authors including Cyert and Degroot (1970), and Kihlstrom and Mirman (1975) have explored using the Bayes process and historical data to infer values of unknown parameters when dealing with an incomplete world view. Bayesian calculations produce an ex post perspective and offer the probability of an event occurring based on historical data. A procedure that makes use of numerical Bayes techniques to develop an underlying predictive density holds significant promise according to Foster and Whiteman (1999). Bayesian estimation provides much richer information than the NHST t test and sometimes comes to different decisions (Kruschke, 2013).

The calculations yielded from the shorter time periods yielded stronger probabilities than those for the 1948-2019 period. To err on the side of generating more conservative forecasts, we focused on reporting only the results from the total data set in this article. Data showed a strong positive correlation between September 1 U.S. hop stocks when used as the independent variable and U.S. SAP as the dependent variable. A positive change in stocks one year meant an 80.77% likelihood that U.S. SAP increased for that year with higher probabilities for such an increase in subsequent years demonstrating similar movements in stocks. The positive correlation between the U.S. HER and the U.S. SAP demonstrated a 77.78% chance in an increase in the U.S. SAP of the following year ($n+1$) increasing with an increase of September 1 stocks in year n. This is the first known documented case of future price prediction ability in the hop industry. Forecasts are limited to directional price movements due to the use of aggregate data reported by the USDA.

The owner of a proprietary variety with complete control and access to price and sales data for a variety could produce forecasts with greater accuracy. Beyond the economic turmoil created by Covid-19 that will cause thousands of American craft breweries to close (Watson, 2020), there will be opportunities for growth of proprietary variety market share at the expense of public varieties. The challenges and variability associated with producing an agricultural commodity will always remain. A forecasting model employing the Bayesian method offers the best opportunity to calculate probabilities of future events. These data, however, when combined with an a priori knowledge of market dynamics, make hop market forecasting future price movements possible.

5　　　　REFERENCES

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