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RESEARCH ARTICLE

KNOW YOURSELF AND KNOW YOUR ENEMY: AN ANALYSIS OF FIRM RECOMMENDATIONS AND CONSUMER REVIEWS IN A COMPETITIVE ENVIRONMENT

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Appendix A

Variables List, Summary Statistics, and Correlation Matrix

Table A1. Variable List and Definitions

	Variable Name	Variable Description
	Log (Sales $Rank_{i,t}$)	Log transformed sales rank for book *i* at time t
Review $Effect_{i,t-1}$	Positive Review Volume	Cumulative count of positive reviews posted to the focal book up to time t-1
	Negative Review Volume	Cumulative count of negative reviews posted to the focal book up to time t-1
	Positive Helpful Vote	Ratio of Helpful vote to Total vote for positive reviews posted to the focal book up to time t-1
	Negative Helpful Vote	Ratio of Helpful vote to Total vote for negative reviews posted to the focal book up to time t-1
	Review Rating Average	Average review rating posted to the focal book up to t-1
	Review Rating StdDev	Standard deviation of review ratings posted to the focal book up to t-1
	Weighted Review Rating	Composite average review rating weighted by the helpful vote posted to the focal book's reviews up to t-1 calculated as *Review Rating Average* * $\left(1+\frac{1+HelpfulVote}{1+TotalVote}\right)$
Rev ewer Effect $_{i,t-1}$	Top Reviewer Agreement	Count of top reviewers who agree on the rating of the focal book up to t-1 normalized by the count of total top reviewers
	Top Reviewer Disagreement	Count of top reviewers who disagree on the rating of the focal book up to t-1 normalized by the count of total top reviewers
	Average of Rating Agreement	Average rating of positive reviews made by all reviewers of the focal book) to other books (besides the focal one) up to t-1
	StdDevofRating Agreement	StdDev of the ratings of positive reviews made by all focal reviewers to other books up to t-1
	Ratio Reviewer Agreement	Ratio of the count of reviewer agreement for the focal book divided by the count of reviewer agreement for the competing book up to t-1

Table A1. Variable List and Definitions (Continued)		
$Referral_{i,t-1}$	Centrality	Eigenvector centrality of the focal book in the recommendation network up to t-1
$Review Effect_{i,t-}$	Competitor Review Rating Average	Average review rating posted to the competing book up to t-1
	Competitor Positive Review Volume	Cumulative count of positive reviews posted to the competing book up to time t-1
	Competitor Negative Review Volume	Cumulative count of negative reviews posted to the competing book up to time t-1
	Competitor Positive Helpful Vote	Ratio of Helpful vote to Total vote that positive reviews posted to the competing book up to time t-1
	Competitor Negative Helpful Vote	Ratio of Helpful vote to Total vote that negative reviews posted to the competing book up to time t-1
	Competitor Weighted Review Rating	Composite average review rating weighted by the helpful vote posted to the competing book's reviews up to t-1
	Competitor Centrality	Eigenvector centrality of the competing book in the recommendation network up to t-1

Table A2. Summary Statistics

Variable	Label	Obs	Mean	Std. Dev.	Min	Max
Pos Review Volume	1	39040	126.147	380.426	1	5430
Neg Review Volume	2	39040	23.737	95.079	0	1593
Pos Helpful Vote	3	39040	0.798	0.145	0.122	1
Neg Helpful Vote	4	39040	0.476	0.250	0	1
Review Rating Average	5	39040	4.356	0.460	1	4
Review Rating Std. Dev.	6	39040	0.948	0.425	0.1	2.309
Weighted Review Rating	7	39040	5.124	4.088	0.7	10
Top Reviewer Agreement	8	39040	0.030	0.107	0	1
Top Reviewer Disagreement	9	39040	0.024	0.104	0	1
Average of Rating Agreement	10	39040	4.295	0.543	1	4
Std. Dev. of Rating Agreement	11	39040	0.902	0.481	0	2.309
Centrality	12	39040	0.112	0.852	0.064	167.165
Competitor Pos Review Volume	13	39040	81.502	232.184	1	3319
Competitor Neg Review Volume	14	39040	15.279	58.061	0	1172
Competitor Pos Helpful Vote	15	39040	0.760	0.208	0	1
Competitor Neg Helpful Vote	16	39040	0.476	0.257	0	1
Competitor Review Rating Avg	17	39040	4.335	0.542	1	5
Competitor Weighted Review Rating	18	39040	2.886	3.908	0	10
Ratio Reviewer Agreement	19	39040	0.103	0.021	0	1
Competitor Centrality	20	39024	0.121	0.084	0.090	151.183

Table A3. Correlation Matrix

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	1																			
2	0.292	1																		
3	-0.257	-0.269	1																	
4	0.046	0.1047	-0.187	1																
5	-0.090	-0.255	0.453	-0.202	1															
6	0.143	0.1909	-0.412	0.1282	-0.233	1														
7	0.079	-0.009	0.101	-0.110	0.0211	0.1072	1													
8	0.316	0.3714	-0.142	0.0038	-0.124	0.0847	0.002	1												
9	0.344	0.211	-0.172	0.049	-0.189	0.1208	-0.030	0.317	1											
10	-0.106	-0.106	0.070	-0.0048	-0.0017	0.0034	0.010	-0.050	-0.074	1										
11	0.035	0.0622	-0.036	0.0084	0.0031	-0.018	0.002	0.029	0.0568	-0.390	1									
12	0.002	-0.0004	0.002	-0.0045	0.0009	0.0003	0.004	0.003	-0.0006	0.001	0.0006	1								
13	0.025	0.0297	-0.013	-0.006	-0.030	0.0184	0.015	0.044	0.0333	-0.010	0.0045	0.0007	1							
14	-0.006	-0.051	0.202	-0.078	0.3033	-0.208	0.058	-0.060	-0.043	0.015	-0.0014	0.0021	-0.009	1						
15	0.161	0.4053	-0.186	0.0228	-0.089	0.1198	0.058	0.123	0.1379	-0.090	0.0045	0.0027	0.0111	-0.030	1					
16	-0.093	-0.119	0.200	-0.058	0.1921	-0.163	0.021	-0.090	-0.094	0.039	-0.018	-0.007	-0.012	0.3002	00.079	1				
17	0.253	0.1884	-0.126	-0.02	-0.118	0.1215	0.012	0.063	0.0511	0.003	-0.010	-0.0006	0.0057	-0.085	0.472	-0.097	1			
18	0.016	0.0578	-0.050	0.1285	-0.072	0.0639	0.005	0.032	0.0161	0.010	-0.0031	-0.0025	0.0036	-0.113	0.060	-0.054	0.097	1		
19	0.124	0.047	0.054	-0.0037	-0.041	0.0973	0.321	-0.080	-0.038	-0.010	0.007	0.0022	-0.0029	0.1006	0.169	0.161	0.005	-0.060	1	
20	0.139	0.1257	-0.057	-0.008	-0.058	0.0609	0.083	0.161	0.132	-0.020	0.0134	0.0044	0.0453	-0.022	0.061	-0.050	0.022	0.024	0.008	1

Appendix B

Statistical Tests of the Econometrics Models

Testing Multicolinearity Using the Variance Inflation Factor (VIF)

The VIFs for all the variables are reported in Table B1. None of them is greater than 10, indicating that multicollinearity is not present here.

Table B1. VIF Values

20	4.59	0.2179
12	4.10	0.2439
5	3.98	0.2511
6	3.61	0.2769
1	3.38	0.2958
9	3.13	0.3196
2	3.08	0.3246
8	2.35	0.4264
13	2.29	0.5374
10	1.98	0.5055
11	1.95	0.5126
3	1.41	0.7071
14	1.34	0.7443
7	1.25	0.8005
18	1.22	0.8165
17	1.21	0.8241
15	1.17	0.8542
4	1.10	0.9118
16	1.05	0.9503
19	1.00	0.9997
Mean VIF	**2.26**	

Testing Fixed Versus Random Effects

The Hausman specification test compares the fixed effects with random effects models under the null hypothesis that the individual effects are uncorrelated with the other regressors in the model (Hausman 1978). If correlated (H_0 is rejected), a random effect model produces biased estimators, violating one of the Gauss-Markov assumptions; so a fixed-effects model is preferred. Hausman's essential result is that the covariance of an efficient estimator with its difference from an inefficient estimator is zero (Greene 2007). We obtained the χ^2 value as

$$\chi^2_{(12)} = (b - B)'[(V_b - V_B)^{-1}](b - B) = 6527.43 \text{ and } p\text{-value} < 0.0001$$

This suggests that the null hypothesis that both FE and RE are consistent estimators is rejected and thus we choose the fixed effects model.

Testing Heteroscedasticity

In our case, we use the modified Wald test for group-wise heteroskedasticity in the residuals of a fixed effects regression model (Greene 2007) where H_0: $\sigma_i^2 = \sigma^2$ for all i. The chi-square with 1194 degree of freedom is $\chi^2_{(1194)} = 22842.40$ with p-value < 0.0001. This indicates the presence of heteroscedasticity and thus we use the robust standard errors to address this issue.

Testing Serial Correlation

We apply the Wooldridge test (2002) for autocorrelation in panel data where the null hypothesis is H_0: no first-order autocorrelation. The $F_{(1,1194)}$ value is = 1284.09 with a p-value<0.0001 rejecting the null hypothesis. The test indicates the presence of serial correlation and hence we explicitly use AR(1) to account for this.

Appendix C

Instrumental Variable Approach

Hausman Test of Endogeneity

Using IV estimation for the sake of consistency must be balanced against the inevitable loss of efficiency. Therefore, we perform a test of endogeneity where, under the null hypothesis, the specified endogenous regressors can actually be treated as exogenous. Durbin–Wu–Hausman (Durbin 1954; Hausman1978; Wu 1973) tests involve estimating the model via both panel and IV approaches and comparing the resulting coefficient vectors (sometimes referred to as the Hausman test). These tests implemented by Hansen–Sargan (Hansen et al. 1996; Sargan 1958) have been modified to accommodate the GMM estimation. The test statistic is distributed as chi-square with degrees of freedom equal to the number of regressors tested.

In this case, $\chi^2_{(4)} = 5.519$ with p-value < 0.001 indicating the preference of the GMM based IV estimations.

Exogeneity Assumption (IV Distributed Independently of the Error)

Because the exogeneity assumption cannot be directly tested, an overidentification test is used instead. In the context of GMM, the overidentifying restrictions may be tested via the commonly employed J-statistic of Hansen (1982), sometimes referred to as Sargan-Hansen J-statistic. This diagnostic statistic is the most commonly utilized in GMM estimation to evaluate the suitability of the model (Baum et al. 2003). The joint null hypothesis is that the instruments are valid ones (i.e., uncorrelated with the error term), and that the excluded instruments are correctly excluded from the estimated equation (Stata Manual 2011). The statistic is distributed as χ^2 with degrees of freedom equal to the number of over-identifying restrictions. In this case, for the *Review* IVs, $\chi^2_{(4)} = 0.52$ with p-value = 0.77. For the *Centrality* IVs, $\chi^2_{(4)} = 1.30$ with p-value = 0.86. Thus both tests fail to reject the null hypotheses, implying that the instruments are valid.

If and only if an equation is overidentified, we may test whether the excluded instruments are appropriately independent of the error process (test referred to as refutability test). That test allows us to evaluate the validity of the instruments. The C-statistic (also known as a "GMM distance" or "difference-in-Sargan" statistic) allows a test of the exogeneity of one or more instruments (Stata Manual 2011). In this case, $\chi^2_{(8)} = 68.78$ with p-value < 0.0001.

Relevance Assumption (IV correlated with Endogenous Variables)

To test the relevance assumption—that the excluded instruments are sufficiently correlated with the included endogenous regressors—we should consider the goodness-of-fit of the first stage regressions relating each endogenous regressor to the entire set of instruments. This is typically done through a Wald F-statistic that is based on the Kleibergen–Paap rank statistic (Kleibergen and Paap 2006) (which is more convenient than the Cragg–Donald–Wald F-statistic when there is more than one IV in the presence of heteroscedasticity). Overall, KP statistics have to be greater than the Stock-Yogo critical values (Stock and Yogo 2005). In this case, for the *Review* IVs, we have *Kleibergen-Paap rk Wald F-statistic* = 285.233 which is greater than 15.72, the critical value of the Stock-Yogo weak ID test at 5 percent maximal IV relative bias. For the *Centrality* IVs, this statistic is 21.655 which is greater than the critical value (18.37).

Generalized Method of Moments Approach

The different steps in the estimation procedure are detailed in Baum et al. (2003) and Chintagunta et al. (2010):

(1) Estimate the regression model using standard instrumental variables methods.
(2) Use the residuals from the above regression to obtain the optimal GMM weighting matrix.
(3) Allow for heteroscedasticity and correlation between error terms.

The GMM estimator and its asymptotic variance are

$$\hat{\beta}_{GMM} = \left[(X'Z)W(Z'X)\right]^{-1}(X'Z)W(Z'y)$$
$$V_{\hat{\beta}_{GMM}} = \left[(X'Z)W(Z'X)\right]^{-1}$$

where X = Matrix of regressors in the model with endogenous variables
Z = Matrix of instruments
y = Dependent variable
W = Optimal weighting matrix

Appendix D

Additional Robustness Checks

Table D1 displays the results of a variation of the extended model with IV. The regression is run on a subset of the data for which price has been recorded. The results are qualitatively consistent, where higher price of the focal book has a positive effect on rank (i.e., driving down sales) and higher price of the competing book drives up the sales of the focal book, both are as expected.

Table D1. Results with Price Included

		Extended Model with IV	
	Log (Sales Rank)	**Robust Coef.**	**p**
Review Effect	Pos Review Volume	-0.0010 (0.0018)	0.0000
	Neg Review Volume	-0.0031 (0.0057)	0.5850
	Review Rating Average	-0.3863 (0.2472)	0.0010
	Review Rating Std Dev	0.2108 (0.0807)	0.0108
Reviewer Effect	Top Reviewer Agreement	-0.0022 (0.0834)	0.0097
	Top Reviewer Disagreement	0.1366 (0.2144)	0.5240
	Avg of Rating Agreement	-0.0556 (0.1378)	0.0100
Referral	Centrality	-0.0721 (0.0118)	0.0005
Computer Effect	Competitor Review Rating Avg	-0.0490 (0.1786)	0.0678
	Competitor Pos Review Volume	0.0007 (0.0010)	0.0010
	Ratio Reviewer Agreement	-0.0800 (0.0119)	0.0500
	Competitor Neg Review Volume	-0.0065 (0.0031)	0.0350
	Competitor Centrality	0.0217 (0.0336)	0.0100
Price	Price of Focal Book	0.0004 (0.0003)	0.045
	Price of Competitor Book	-0.0008 (0.0001)	0.039

Table D2 displays the results of a variation of the extended model with IV where the regression is run on a subset of the data for which the dependent variable is the log of the difference in sales rank between the focal book and its competitor. All of the results remain qualitatively consistent.

Table D2. The Results with a New Dependent Variable (log of the difference between sales ranks of the focal and competing book)

	Log (Δ Sales Rank of Focal and Competitor)	Extended Model with IV	
		Robust Coef.	p
Review Effect	Pos Review Volume	-0.0001 (0.0003)	0.0220
	Neg Review Volume	0.00011 (0.00096)	0.2350
	Review Rating Average	-0.07009 (0.03965)	0.0070
	Review Rating Std Dev	-0.07187 (0.03010)	0.0170
Reviewer Effect	Top Reviewer Agreement	-0.00119 (0.00130)	0.0359
	Top Reviewer Disagreement	-0.00412 (0.00412)	0.1560
	Avg of Rating Agreement	-0.00731 (0.00358)	0.0410
Referral	Centrality	-0.02128 (0.01195)	0.0750
Computer Effect	Competitor Review Rating Avg	0.00250 (0.00557)	0.6540
	Competitor Pos Review Volume	0.00007 (0.00003)	0.0000
	Competitor Neg Review Volume	-0.00020 (0.00008)	0.0160
	Reviewer Ratio Agreement	-0.04510 (0.07720)	0.0099
	Competitor Centrality	0.05117) (0.00732)	0.0000

Table D3 displays the results of a variation of the extended model with IV. The regression is run on a one-day and three-day time window, as opposed to the one-week window we use in the paper. The results show the same general trends.

Table D3. Results with a One-Day and Three-Day Time Window					
		Extended Model with IV			
		One-Day Interval		Three-Day Interval	
	Log (Sales Rank)	Robust Coeff.	p	Robust Coef.	p
Review Effect	Pos Review Volume	-0.0002 (0.0001)	0.0360	-0.0006 (0.0002)	0.0100
	Neg Review Volume	0.0002 (0.0002)	0.624	0.0005 (0.0005)	0.454
	Review Rating Average	-0.0568 (0.0428)	0.045	-0.1704 (0.0643)	0.035
	Review Rating Std Dev	-0.0057 (0.0173)	0.045	-0.0142 (0.0433)	0.04
Reviewer Effect	Top Reviewer Agreement	-0.0065 (0.0080)	0.0340	-0.0098 (0.0100)	0.029
	Top Reviewer Disagreement	0.0037 (0.0099)	0.701	0.0065 (0.0110)	0.648
	Avg of Rating Agreement	-0.0087 (0.006)	0.039	-0.0209 (0.0112)	0.045
Referral	Centrality	-0.3080 (0.0452)	0.026	-0.2224 (0.0769)	0.015
Computer Effect	Competitor Review Rating Avg	0.0088 (0.0159)	0.043	0.0193 (0.0128)	0.039
	Competitor Pos Review Volume	0.0001 (0.0001)	0.003	0.0003 (0.0001)	0.024
	Competitor Neg Review Volume	-0.00003 (0.0002)	0.015	-0.00003 (0.0004)	0.029
	Reviewer Ratio Agreement	-0.1549 (0.0293)	0.024	-0.1033 (0.0646)	0.018
	Competitor Centrality	0.1174 (0.0475)	0.029	0.2699 (0.0271)	0.0143

Appendix E

Construction of Variables

We detail below our approach to constructing several of the main variables in this paper.

Centrality

This measure is based on an Amazon recommendation feature labeled *Customers Who Bought This Item Also Bought*. We illustrate our construction of *Centrality* with graphs that represent the network of referrals.

In Figure E1, we start with book A1 at level 0 which represents the initial focal book. Then at level 1, we identify the books recommended when viewing book A1 (out-links); suppose these are books B1 through B10 (with loss of generality, assuming 10 books are recommended). At level 2, we do the same for each of the books B1 through B10 (each now becoming a focal book itself) by identifying books recommended along with each of these 10 books (i.e., out-links toward books C1–C10, D1–D10, …). We then repeat the same process at level 3. In this example, we end up with 1,110 books recommended one level away from book A1. Similarly, for all the 1,470 books in our dataset, this yields a theoretical total of 1,931,400 books recommended along with books A1 through A1740 (across all levels). These almost two million books constitute the universe we consider in this study.

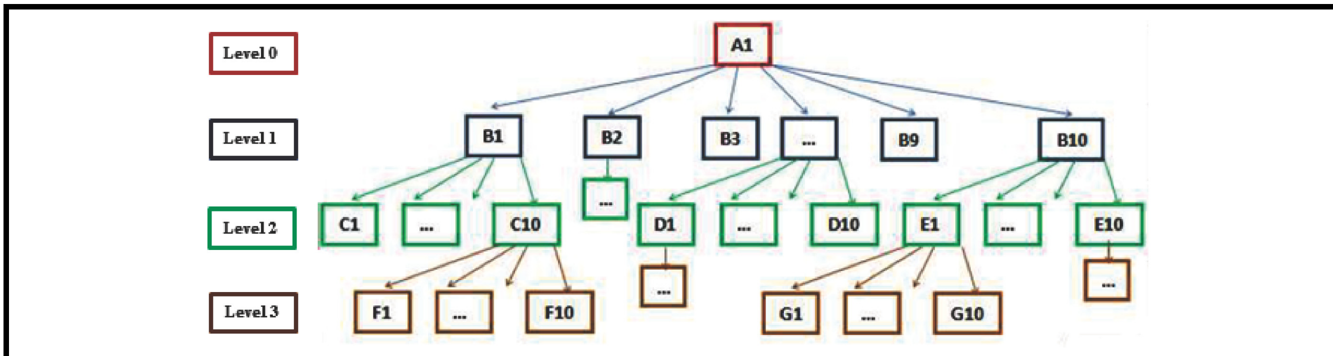

Figure E1. Theoretical Diagram

Note, however, that within these nearly two million books, a very large number of the links reverts back to books 1 to 1,740. Thus, the theoretical diagram displayed in Figure E1 reverts in practice to the more parsimonious diagram in Figure E2. Here, each book becomes a source book that refers users to other related books (out-links). It also becomes a sink that attracts users from related books through referrals (in-links). This results in a directed network of books referring to each other.

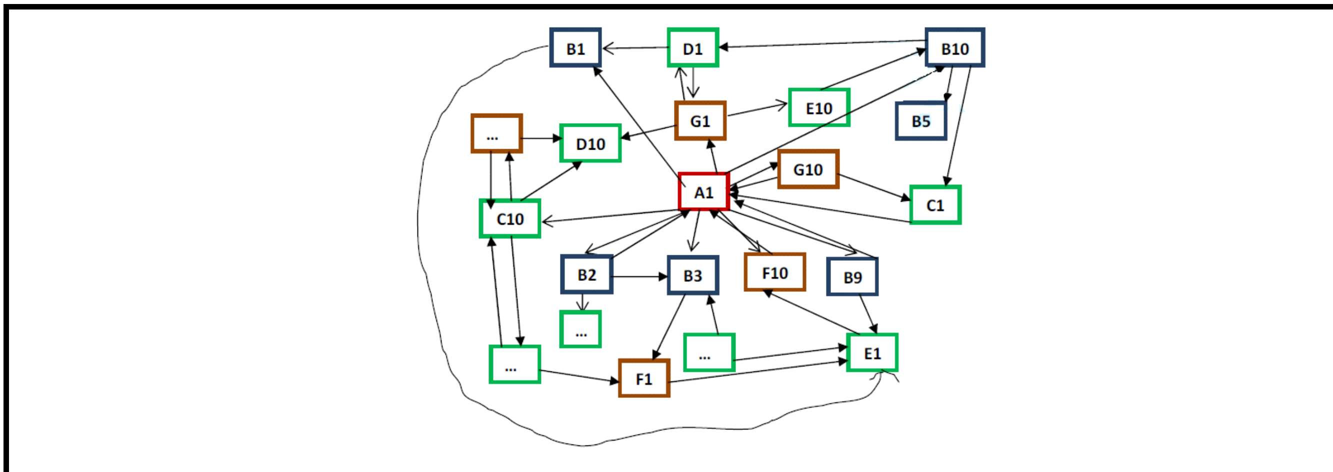

Figure E2. Parsimonious Diagram

We then calculate the eigenvector centrality for each of the books in our database, and label it *Centrality*. The eigenvector approach measures the importance of a node within a directed network based on its linkages with other high-scoring nodes and it factors in both sides of directions[1] (different variants of this approach have been recently used in social media contexts[2]). This allows us to find the most central actors within the global structure of the network.

[1]Eigenvector centrality is viewed as a simple yet robust measure similar to the HITS algorithm of Kleinberg (1998) and Google's PageRank algorithm (Brin and Page, 1998). Given a set of n web pages (say, retrieved in response to a search query), the algorithm first forms a n-by-n adjacency matrix A whose (i, j)-element is 1 if page i links to page j, and 0 otherwise.

[2]Different variants of these algorithms have been recently used in social media contexts to evaluate the "authority" of users (Zhang et al. 2007) and quality of content (Agichtein et al. 2008), among other considerations.

Pseudo-Lift as IV for Centrality

The pseudo-lift measure that we derive is used as IV for *Centrality*. It builds on the notion of lift for association rule discovery in data mining. In that context, an association rule links one or several antecedent items to one or several consequent items as being purchased together. In our context, the consequent is always the focal book and the antecedent(s) is(are) other books recommended along with the focal book. A representative association rule is of the sort $\text{RecommendedBook}_{ij} \rightarrow \text{FocalBook}_i$. Confidence is defined as the likelihood of observing both a recommended book and the focal book, given that the recommended book has been observed. We, therefore, operationalize Pseudo-Lift as

$$PseudoLift_{ij} = \frac{Confidence(Recommended_{ij} \rightarrow Focal_i)}{Support(Focal_i)}$$
$$= \frac{Support(Recommended_{ij}\ \ AND\ \ Focal_i) \,/\, Support(Recommended_{ij})}{Support(Focal_i)}$$
$$= \frac{Support(Recommended_{ij}\ \ AND\ \ Focal_i)}{Support(Recommended_{ij})\ \ *\ \ Support(Focal_i)}$$

At any given time, multiple books *j* would be recommending the focal book *i*. We use the same approach identified earlier with centrality to discover the set of recommended books *j*. We end up with several rules in which focal book *i* is the consequent. We aggregate these rule to derive the pseudo-lift at the focal book level as follows:

$$PseudoLift_i = \frac{\sum_j PseudoLift_{ij}}{|J|}$$

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