RISK ASSESSMENT OF EVENTS OF INTEREST FOR THE BRAZILIAN AGRICULTURAL SECTOR BASED ON A PSYCOMETRIC MODEL FOR ORDINAL PREFERENCES

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ABSTRACT

This paper uses the Law of Categorical Judgments to rank events of importance for the Brazilian agricultural sector as well as the level of public policies carried out by the government to mitigate their effects, according to the perceptions of 502 sector specialists. Statistical results point to infrastructure and logistics as the most important factors with lowest level of public policies in place. Traditional subjects such as credit, animal and vegetal health remain important according to the specialists perceptions and show a relatively high level of public policies in place.

KEYWORDS. Law of Categorical Judgment. Psychometrics. Policies. Agriculture.

AG & MA - OR in Agriculture and Environment; EST - Statistics; PM - Probabilistic Models

1. Introduction

The agricultural sector is subject to several uncertainties, such as market risks (price, production and exchange rate volatility), weather, and biological factors, which historically required government attention and public programs and policies. Recently, with agricultural modernization and expansion, other subjects - such as production management, climate change, natural resource management, legal framework, among others - became relevant in the discussions about the sector future and should be addressed by policy makers.

Changes in agricultural priorities were usually a result of different factors, for instance, science progress, conjunctural economic factors, government strategy, and sector specificities. However, while economic development allows overcoming some bottlenecks and fragilities, it also creates new challenges.

During development and modernization changes, the government has an essential role acting as a supporter of the production sectors of the economy (Baer et. al, 1973, Haj-Omar, 2001). This occurs because when there are uncertainties, private agents act cautiously, and in order to reduce uncertainties about future investments, it is necessary State intervention (Keynes, 1997).

The government intervenes in the economy through public policies. According to Mattos and Hercowitz (2011), public policies are a set of concepts and objectives developed to solve problems. Nevertheless, as in every planning process, policy execution needs constant improvement. Birkland (2007) emphasizes that to prioritize problems in the policy agenda is not enough to define an order of priorities at one time, but it is necessary to construct. Additionally, the authors argue that problems have to be described emphatically and with accuracy in order to get government attention and to be included in public policies.

Aiming to contribute to the discussion about challenges and priorities of the agricultural sector, this work uses an application of psychometrics of ordinal scale to compare and to prioritize ten selected subjects in the agricultural sector, and the level of government action (public policies in place) on these subjects, according to specialists. The main goal is through specialists´ answers to identify areas that should be emphasized by policymakers in order to solve bottlenecks and inefficiencies of the Brazilian agricultural sector.

This paper is organized in four sections, which are the following: this introduction, section 2 presents the methodology, section 3 presents results and section 4 concludes.

2. Methodology

2.1. Data

From a workshop organized to discuss the future of Brazilian agriculture, which took place at Embrapa, ten subjects were considered essential to develop the future of Brazilian agricultural sector: A) extreme weather events and fire; B) animal health; C) plant health; D) production management; E) natural resources management; F) market/commercialization; G) credit; H) international trade; I) regulatory framework and interest conflict; and J) infrastructure and logistics.

The subjects above were submitted to 502 specialists from the agricultural sector, including academics, researchers, producers, that expressed their opinion about the relative importance of the subjects and their perceptions about the level of the actual government policies on each one of the subjects.

In order to measure specialists' perception, a Likert scale was used and according to Silva Júnior e Costa (2014), this scale is the most used model to measures attitude in the context of behavioral sciences. We defined a scale with five measurements points: 1= very low; 2= low; 3=medium; 4=high; 5=very high. Data were presented on contingency tables, and they identify the frequencies of responses from 1 to 5.

2.2 The psychometric scale method

According to the behavioral mental model proposed by Thurstone (1927), an individual expresses his/her preferences according to a set of stimuli and associates each stimulus to a real number μ_i in his/her psychological continuum, in a way to express preferences in a categorized order.

According to Souza (2002), while the stimuli are translated into scale values $\mu_1,\ldots,\mu_r$, categories are translated into localization values $\tau_1,...,\tau_{m-1}$. These quantities define a partition of the real line $(-\infty,\tau_1]$, $(\tau_1,\tau_2]$,..., $(\tau_{m-1}, +\infty)$ where stimuli S_i are associated to categories C_j according to the following rule: the individual classify stimulus S_i into $U_{l=1}^{j}C_l$ if and only if $\mu_i \leq \tau_j$.

The process is random due to the sample of individuals (judges) and to stochastic fluctuations in the values and localization scales in the psychological continuum. This occurs when the same individual evaluates repeatedly a given stimulus and category. Souza (1998) defines this process as psychological behavior of Thurstone´s Law. For more details explore Saaty (1994), Johnson & Kotz (1989), Souza (1988) e Torgenson (1958).

The differences in individual behavior (judges that are part of the sample) support the hypothesis that μ_i are means of random variables ξ_i with variance σ_i^2 and τ_j are means of random variables η_j with variance ϕ_j^2. We assume independency in the judgement of stimulus and joint normality, allowing inferring that ξ_i are not correlated and the pairs (ξ_i,η_j) are jointly normally distributed. From a statistical point of view, the interest is in the parametric difference between stimuli represented by $\mu_i-\mu_j$. These quantities will be used to evaluate the differences in intensity between stimuli.

Let π_{ij} be the probability of locating stimulus S_i in one of the *j* first categories $C_1, C_2, \ldots, C_j$. Suppose π_{ij} □ 0 for any choice of pair *(i, j)*. We have:

$$p\left\{s_i \in \overset{j}{\underset{l=1}{U}} c_l\right\}\pi_{ij} i=1,\ldots,r,\ j=1,\ldots,m-1.$$
$$= p\left\{\xi_i \leq \eta_j\right\}$$
$$= p\left\{Z \leq -\frac{\mu_i-\tau_j}{\sqrt{Var(\xi_i-\eta_j)}}\right\}$$

Let *g(.)* be an inverse function of the standard normal distribution:

$$F(x)=\int_{-\infty}^{X}\frac{1}{2\pi}\exp\left(\frac{-t^2}{2}\right)dt$$

Thus, the assumption of jointly normality leads to the equations:

$$g(\pi_{ij})=-\frac{\mu_i-\tau_j}{\sqrt{Var(\xi_i-\eta_j)}}\, i=1,...,rj=1,\ldots,m-1$$

that relates the cumulative probabilities π_{ij} with parameters μ_i, τ_j and variances from Thurstone´s model. It is possible to generalize the normal projection into the psychological *continuum* in order to allow the use of others distributions. Typically, competitors from the

"probit" answer are given by the logistics and log-log scale. The g(.) functions are:

$g(x) = \ln(x/(1-x))$ e $g(x) = \ln(-\ln(1-x))$ respectively.

Suppose that initially we have enough observations to estimate the probabilities π_{ij}. Therefore, we obtain the sample version of the following Law of Categorical Judgment:

$$g(\hat{\pi}_{ij}) = -\frac{\mu_i - \tau_j}{\sqrt{Var(\xi_i - \eta_j)}} + u_{ij} i = 1,\ldots, rj = 1,\ldots, m-1$$

where $\hat{\pi}_{ij}$ estimates π_{ij} and the vectors $u_i' = (u_{i1,\ldots,} u_{im-1})$ are independently distributed with a distinct variance matrix for each *i*. The linear version of the Law of Categorical Judgment assumes $Var(\xi_i - \eta_j)$ constant and, consequently, the model:

$$g(\hat{\pi}_{ij}) = \tau_j - \mu_i + u_{ij} i = 1,\ldots, rj = 1,\ldots, m-1$$

With this level of generality, it is not possible to estimate μ_i, which can be solved through imposing $\sum_i \mu_i = 0$ or turning one of μ_i=0, since we are primarily interested in the contrasts $\mu_i - \mu_j$.

In the next step, we estimate the model using the maximum likelihood method. This approach allows the use of distributions different from the standard normal to model the probabilities of stimuli classification in the categories of responses. The advantage of this method is that it can be used even when there are zero frequencies in the contingency table. However, Souza (2002) warns that this approach might fail in cases where there are sparse tables, and there are high proportions of frequencies lower than five. In this case, the author recommends some strategies such as to add a constant in all cells of the table or a constraint in the cells with problems; or to combine some classes of answers; or to eliminate stimulus.

2.3 The maximum likelihood estimator

In order to determine the maximum likelihood estimator, we assume that the totals in the rows are fixed and we search for the parameters values μ_i e τ_j that maximize the function:

$$\sum_{i=1}^{r}\sum_{j=1}^{m} y_{ij} \ln(p_{ij})$$

where $p_{im} = 1 - \sum_{j=1}^{m-1} pij$ for each row *i* and:

$$p_{i1} = g^{-1}(\pi_l - \mu_i)$$
$$p_{ij} = g^{-1}(\tau_j - \mu_i) - g^{-1}(\tau_{j-1} - \mu_i)\, j = 2,\ldots, m-1$$

Subject to one of the restrictions $\sum_i \mu_i = 0$ $_i$ or μ_r

Souza (2002) explains that this approach has the computational advantage of being implemented in SAS through a simple application of PROC GENMOD. McCullagh & Nelder (1989) used a linear version of the Law of Categorical Judgment in an ordinal scaled multinomial model. This process is compatible with all three alternative functions to the normal distribution: probit, logistic and log-log. In order to verify the goodness of fit, one can use: the analysis of

deviance, Pearson, over dispersion and examining the contrast $\mu_i - \mu_j$ significance.

Defining the relative importance of stimulus S_i as:

$$\frac{\frac{1-\pi_{ij}}{\pi_{ij}}}{\sum_{v=1}^{r}\left(\frac{1-\pi_{vj}}{\pi_{vj}}\right)}$$

These quantities are weights that sum 1. For the logistic function, quantities

$$\frac{\frac{1-\pi_{ij}}{\pi_{ij}}}{\sum_{v=1}^{r}\left(\frac{1-\pi_{vj}}{\pi_{vj}}\right)} = \frac{e^{\mu_i}}{\sum_v e^{\mu_v}}$$

are not dependent on category j, and they measure relative importance. Thus, the higher μ_i the more important is the correspondent stimulus. In this context, if ratios $\frac{r_i}{r_j}$ are significantly different from one, this is equivalent to the significance analysis of contrasts $\mu_i - \mu_j$ analysis.

3. Results

3.1 Frequencies of responses to stimuli

Tables 1 e 2 (contingency tables) show frequencies of responses to ordinal categories 1, 2, 3, 4, e 5 to the ten stimuli, identified by A, B, C, D, E, F, G, H, I, J. The main goal when analyzing these tables is to categorize in a 1 to 5 scale, where 1 represents less e 5 higher intensity.

Table 1 shows infrastructure and logistic as the subject with more type 5 answers, thus, is considered as a strong priority subject, followed by animal and vegetable health and natural resources management.

Table 1. Frequencies of responses: subject importance

	Categories/importance	**1**	**2**	**3**	**4**	**5**
A	Extreme Weather Events and Fire	6	26	70	169	162
B	Animal Health	3	15	39	160	204
C	Plant Health	2	15	33	178	198
D	Production Management	4	31	104	165	124
E	Natural Resources Management	6	21	69	158	173
F	Market-Commercialization	8	21	93	182	118
G	Credit	2	22	86	185	127
H	International Trade	6	21	96	172	119
I	Regulatory Framework and Interest Conflict	7	22	116	140	123
J	Infrastructure and Logistics	7	8	22	81	306

Table 2 presents specialists´ perceptions about how the government is acting to deal with each one of the subjects. In other words, government actions are policies put in place to solve/improve issues in one of the subjects. Again, the infrastructure and logistics subject

emerges, and presents the higher number of type 1 answer, which means that there are not enough policies in these areas. Looking at type 1 answers, for other categories, specialists evaluated extreme weather events and fire as the second subject with less public policies. On the other hand, animal health, which was the second subject in importance, displayed most of its answers in type 3 and 4, this means that is relatively well considered by the government. Credit is the subject with more type 5 answers and less type 1 answers, thus, is the subject with more public policies, according to specialists' perception.

Table 2. Frequencies of responses: public policies in place for each subject

	Categories/importance	**1**	**2**	**3**	**4**	**5**
A	Extreme Weather Events and Fire	93	179	107	41	12
B	Animal Health	24	93	164	111	11
C	Plant Health	37	114	164	88	13
D	Production Management	75	174	128	36	5
E	Natural Resources Management	73	150	147	48	9
F	Market-Commercialization	46	136	165	56	7
G	Credit	13	70	166	137	24
H	International Trade	38	112	159	75	8
I	Regulatory Framework and Interest Conflict	57	155	137	35	5
J	Infrastructure and Logistics	160	155	62	24	18

Combining columns 1 and 2 (less intensity) and columns 3, 4 and 5 (more intensity) and observing the ranking, we confirm that credit and animal health are the two subjects with more public policy concern, while infrastructure and logistics and extreme weather events and fire are the ones with less public policy attention.

3.2 Relative importance according to ordinal scale

The next step was to define, among the three available functions, which would be the more adequate to be used when defining the priority proportions (low/high) and public policy in place (low/high). For both categories, the logistic function was the appropriate one, because it presented the lower Akaike test (Table 3).

Table 3. Model Choice

	Priority	**Public Policies**
	AIC	**AIC**
Logistic	288,9635	313,9061
Probit	319,5685	349,1540
Log-log	413,1833	364,1685

The *goodness of fit* was tested using the *deviance*, and the model with lower deviance was the logistic. We also used the 'scale deviance' test and Table 4 below shows that the model adjusts to data for both priority and public policies, according to specialists´ perceptions.

Table 4. Goodness of Fit

	Categories	**df**	**Value/dl**	**p value**
Priority	'Scaled deviance'	27	2,2922	1,0000
Policy Action	'Scaled deviance'	27	2,7508	1,0000

Using the maximum likelihood method (MLE), we obtained the relative importance of the ten subjects selected, according to specialists' perception (Table 5). The results confirm infrastructure and animal health as the most important subjects.

Table 5. Relative subject importance – decreasing order

	Categories	MLE
J	Infrastructure and Logistics	32,3850
B	Animal Health	12,6290
C	Plant Health	12,2962
E	Natural Resources Management	8,4308
A	Extreme Weather Events and Fire	7,5300
G	Credit	6,0526
H	International Trade	5,3908
F	Market-Commercialization	5,3591
D	Production Management	5,0389
I	Regulatory Framework and Interest Conflict	4,8876

We also evaluated specialists´ perception about public policies in place (Table 6). We observe credit and animal health perceived by specialists as the subjects that get more attention from the government and consequently more public policies in place, compared to other subjects. Infrastructure and logistics and extreme weather events and fire are the ones that need more public policies.

Tabela 6-. Public Policies in Place

	Categories	MLE
G	Credit	26,6199
B	Animal Health	17,2422
C	Plant Health	12,6273
H	International Trade	11,1647
F	Market-Commercialization	8,5596
E	Natural Resources Management	6,2944
I	Regulatory Framework and Interest Conflict	5,9421
D	Production Management	4,9538
A	Extreme Weather Events and Fire	4,4214
J	Infrastructure and Logistics	2,1746

Figure 1 summarizes the two categories of specialists´ perception. The vertical axis (EMV1) shows specialists´ perception about priorities/importance. The horizontal axis (EMV2) shows specialists´ perception about government action/public policies in place. We observe infrastructure and logistics (J) located in the left superior quadrant, indicating high priority and low public policies in place. Animal health (B) and plant health (C) are located in the right superior quadrant, which means that they receive more government attention, when compared to others.

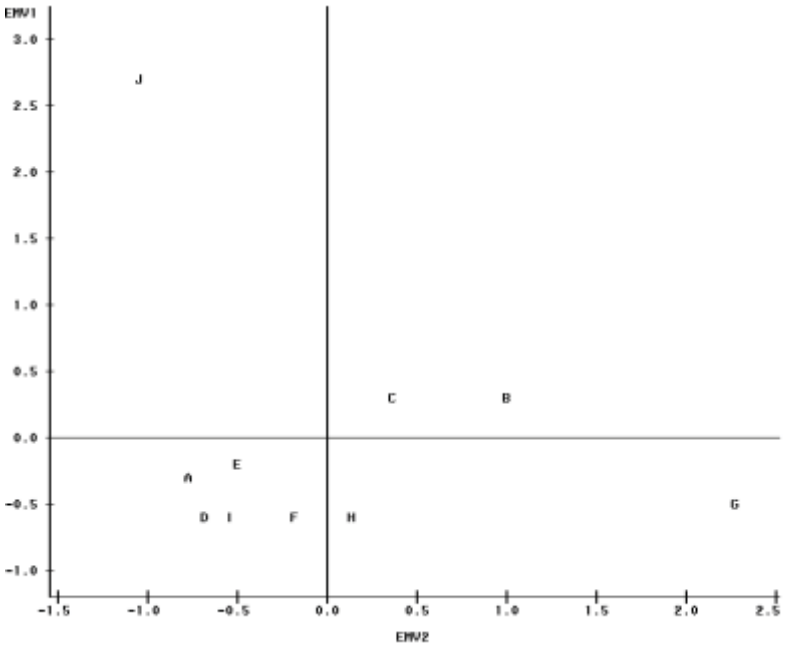

Figura 1. Agricultural subjects and quadrant location.

The following subjects were considered as high priority and low government action, which means that public policies are necessary: Extreme Weather Events and Fire (A), Production Management (D), Natural Resources Management (E), Regulatory Framework and Interest Conflict (I) Market-Commercialization (F). Subjects that showed higher government action: Credit (G) and International Trade (H) were also considered as low priority.

3.3 Stimulus Contrasts among categories

When we looked at pairwise contrasts related to subject priority perception, we found a p-value statistically significant at 1% most of the time except:

(a-e) Extreme Weather Events and Fire x Natural Resources Management
(b-c) Animal Health x Plant Health
(d-f) Production Management x Market-Commercialization
(d-g) Production Management x Credit
(d-h) Production Management x International Trade
(e-j) Natural Resources Management x Infrastructure and Logistics
(f-g) Market-Commercialization x Credit
(f-h) Market-Commercialization x International Trade
(f-j) Market-Commercialization x Infrastructure and Logistics
(g-j) Credit x Infrastructure and Logistics

When looking at government attention perception, we found a p-valor significantly significant at 1% for most of the pairwise contrasts, except:

(a-d) Extreme Weather Events and Fire x Production Management
(c-h) Plant Health x International Trade
(d-i) Production Management x Regulatory Framework and Interest Conflict
(e-i) Natural Resources Management x Regulatory Framework and Interest Conflict

Appendix 1 and 2 present the significance of the differences and also the ratios. Among the evaluated subjects, we observe that extreme weather events and fire dominates other subjects, except for natural resources management, which is a subject that is getting more attention and it is creating more discussions in the sector in the last years. In this sense, it is important to highlight that we did not find differences between natural resources management and infrastructure and logistics.

Moreover, classical subjects such as animal and plant health presented a relevant dominance with respect to other subjects.

When looking at government attention, we found that there were significant differences for all categories analyzed.

4. Conclusions

Results indicate infrastructure and logistics as the most important subject for the agricultural sector and the one with less programs and public policies in place. We found that ´traditional´ subjects, such as animal health and credit, remained important, from specialists´ perception, and they have a relatively high level of government attention through programs and public policies.

This outcome is expected because of the history of animal health and credit policies adopted through time. However, this does not mean that all problems are solved in these two areas and that they do not deserve a solid government attention. Results sustain the thesis that the development of the sector, with the increase in agricultural production and in complexity, creates new challenges such as climate change and natural resources management. Besides, the results showed that these subjects are not getting the government attention needed or in the magnitude required, according to specialists.

To claim that logistics is more important than animal health and credit is not entirely correct, given that perceptions are circumstantial and temporary. The importance of this work is the problem characterization and warning to policy makers. The pathway is to increase discussions in the different areas and subjects of the sector to find alternative solutions that can get policy makers attention.

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Table Appendix 1. Subjects of Interest in the Agricultural Sector Comparison

Comparison	$\mu i - \mu j$	ri/rj	**Chi-Squared**	**p-value**
'a-b'	-0,5171	0,5962	16,26	<0,0001
'a-c'	-0,4903	0,6124	14,92	0,0001
'a-d'	0,4017	1,4944	10,15	0,0014
'a-e'	-0,1129	0,8932	0,79	0,3750
'a-f'	0,3402	1,4052	7,32	0,0068
'a-g'	0,2184	1,2441	3,03	0,0818
'a-h'	0,3342	1,3968	6,98	0,0082
'a-i'	0,4322	1,5407	11,37	0,0007
‘a-j’	-1,4588	0,2325	107,59	<0,0001
'b-c'	0,0268	1,0271	0,04	0,8350
'b-d'	0,9189	2,5064	51,32	<0,0001
'b-e'	0,4042	1,4981	9,81	0,0017
'b-f'	0,8573	2,3567	45,00	<0,0001
'b-g'	0,7355	2,0866	33,27	<0,0001
'b-h'	0,8513	2,3427	43,84	<0,0001
'b-i'	0,9494	2,5840	53,07	<0,0001
‘b-j’	-0,9417	0,3900	44,10	<0,0001
'c-d'	0,8921	2,4402	49,38	<0,0001
'c-e'	0,3774	1,4585	8,73	0,0031
'c-f'	0,8305	2,2945	43,12	<0,0001
'c-g'	0,7088	2,0315	31,54	<0,0001
'c-h'	0,8245	2,2808	41,98	<0,0001
'c-i'	0,9226	2,5158	51,13	<0,0001
'c-j'	-0,9684	0,3797	47,42	<0,0001
'd-e'	-0,5147	0,5977	16,40	<0,0001
'd-f'	-0,0616	0,9403	0,24	0,1427
'd-g'	-0,1833	0,8325	2,15	0,5917
'd-h'	-0,0676	0,9347	0,29	0,8111
'd-i'	0,0305	1,0310	0,06	<0,0001
'd-j'	-1,8605	0,1556	174,33	0,0003
'e-f'	0,4531	1,5732	12,80	0,0088
'e-g'	0,3314	1,3929	6,87	0,0004
'e-h'	0,4471	1,5638	12,31	<0,0001
'e-i'	0,5452	1,7249	17,83	<0,0001
'e-j'	-1,3458	0,2603	90,69	0,3288
'f-g'	-0,1217	0,8854	0,95	0,9622
'f-h'	-0,0060	0,9941	0,00	0,4691
'f-i'	0,0921	1,0965	0,52	<0,0001
'f-j'	-1,7989	0,1655	164,07	0,3561
'g-h'	0,1158	1,1227	0,85	0,0925
'g-i'	0,2138	1,2384	2,83	<0,0001
'g-j'	-1,6772	0,1869	143,25	0,4436
'h-i'	0,0980	1,1030	0,59	<0,0001
'h-j'	-1,7930	0,1665	161,35	<0,0001
'i-j'	-1,8910	0,1509	175,32	0,0003

Table Appendix 2. Public Policies in Place Comparison

Comparison	$\mu i - \mu j$	ri/rj	Chi-Squared	p-value
'a-b'	-1,3609	0,2564	112,65	<0,0001
'a-c'	-1,0494	0,3501	68,20	<0,0001
'a-d'	-0,1137	0,8925	0,82	0,3638
'a-e'	-0,3533	0,7024	7,91	0,0049
'a-f'	-0,6606	0,5165	27,52	<0,0001
'a-g'	-1,7953	0,1661	194,49	<0,0001
'a-h'	-0,9264	0,3960	52,13	<0,0001
'a-i'	-0,2956	0,7441	5,42	0,0200
‘a-j’	0,7096	2,0331	30,12	<0,0001
'b-c'	0,3115	1,3654	6,01	0,0142
'b-d'	1,2472	3,4804	95,66	<0,0001
'b-e'	1,0076	2,7391	62,68	<0,0001
'b-f'	0,7003	2,0143	30,48	<0,0001
'b-g'	-0,4344	0,6477	11,71	0,0006
'b-h'	0,4345	1,5442	11,43	0,0007
'b-i'	1,0652	2,9015	68,35	<0,0001
‘b-j’	2,0705	7,9284	241,38	<0,0001
'c-d'	0,9357	2,5490	54,78	<0,0001
'c-e'	0,6962	2,0060	30,48	<0,0001
'c-f'	0,3888	1,4752	9,52	0,0020
'c-g'	-0,7458	0,4743	34,54	<0,0001
'c-h'	0,1231	1,1310	0,93	0,3360
'c-i'	0,7538	2,1250	34,76	<0,0001
'c-j'	1,7590	5,8066	177,74	<0,0001
'd-e'	-0,2395	0,7870	3,67	0,0555
'd-f'	-0,5469	0,5787	19,04	<0,0001
'd-g'	-1,6815	0,1861	172.56	<0,0001
'd-h'	-0,8126	0,4437	40,51	<0,0001
'd-i'	-0,1819	0,8337	2,07	0,1506
'd-j'	0,8233	2,2780	40,63	<0,0001
'e-f'	-0,3074	0,7354	6,01	0,0142
'e-g'	-1,4420	0,2365	127,66	<0,0001
'e-h'	-0,5731	0,5638	20,17	<0,0001
'e-i'	0,0576	1,0593	0,21	0,6494
'e-j'	1,0628	2,8945	67,02	<0,0001
'f-g'	-1,1346	0,3215	79,80	<0,0001
'f-h'	-0,2657	0,7666	4,35	0,0370
'f-i'	0,3650	1,4405	8,27	0,0040
'f-j'	1,3702	3,9361	110,23	<0,0001
'g-h'	0,8689	2,3843	45,72	<0,0001
'g-i'	1,4996	4,4799	134,63	<0,0001
'g-j'	2,5048	12,2413	349,42	<0,0001
'h-i'	0,6307	1,8789	23,86	<0,0001
'h-j'	1,6359	5,1342	151,20	<0,0001
'i-j'	1,0052	2,7325	58,73	<0,0001