

# Final Project

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## Analyzing Video Game Sales

### Summary

A few sentences describing the inferential question(s), the method used and the most important results.

### Introduction

A more in-depth introduction to the inferential question(s) of interest.

The video game industry has been growing consistently during the last two decades, and in 2017 it was worth more than 78 billion USD worldwide. Video game software sales account for around 80% of total revenue. There are several factors that influence whether a video game will be successful or not, such as the developer studio, the critics rating, the user rating, among others. I will build a model to analyze what factors can help us determine how successful will a video game be in terms of global sales.

I analyzed a total of 4195 video game software releases across the world by 50 different developers. I built a hierarchical linear model on a logarithmic transformation of the global sales, with random slopes by developer, using a manual stepwise selection process using BIC and conditional R-squared as selection criteria. The variables on the final model were found to be significant in predicting the global sales for a video game.

The goal of this project is to find what are the most significant predictors for a video games success, measured as the number of sales around the world. I use a hierarchical linear regression model to explain the number of sales a particular videogame has. Considering that the developing studio plays a major role on a customer's decision to buy a new game, and due to the fact that accounting for every single studio included in the dataset (444 total) would make the interpretation too complicated, I used a random sample of 50 developers and built an appropriate hierarchical model with random intercepts effects for each one of them.

### Data

The data was obtained from Kaggle (<https://www.kaggle.com/rush4ratio/video-game-sales-with-ratings>). It contains data from video games with 100,000 or more global sales from 1976 to 2016. The data contains 16719 rows with the following columns:

- *name* (categorical): Name of the video game
- *platform* (categorical): PPlatform or console for which the video game was released
- *year\_of\_release* (categorical): Year of first release
- *genre* (categorical): Genre of the video game
- *publisher* (categorical): Publishing company
- *na\_sales* (numerical): Units sold in North America
- *eu\_sales* (numerical): Units sold in Europe
- *jp\_sales* (numerical): Units sold in Japan
- *other\_sales* (numerical): Units sold in the rest of the world
- *global\_sales* (numerical): Total units sold worldwide
- *critic\_score* (numerical): Average score (from 0 to 100) according to critics from other media aggregated by Metacritic
- *critic\_count* (numerical): Number of critics taken into account for the Metacritic critic score

- *user\_score* (numerical): Average score (from 0 to 100) according to Metacritic users
- *user\_count* (numerical): Number of user scores on Metacritic
- *developer* (categorical): Video game developing company
- *rating* (categorical): Video game rating according to the ESRB that indicates the appropriate audience

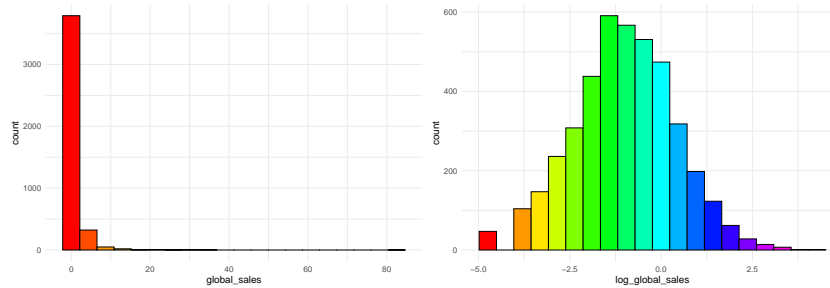
Around half of the rows in the dataset have missing values. First of all, I filtered out every video game release before 2000 since it seemed that for older releases there was more missing data and this report is only concerned with more recent releases. After observing the rest of the rows, the missing data seemed to be at random, so I decided to use only the 6951 rows with complete data.

Since the categorical variables have many levels (See Appendix 1.1 for a summary of the dataset *vgsales*) and in order to center the numerical variables to avoid multicollinearity issues, I created the following additional columns:

- *critic\_score\_c* (numerical): Values of *critic\_score* minus the column's mean value
- *critic\_count\_c* (numerical): Values of *critic\_count* minus the column's mean value
- *user\_score\_c* (numerical): Values of *user\_score* minus the column's mean value
- *user\_count\_c* (numerical): Values of *user\_count* minus the column's mean value
- *platform\_company* (categorical): Company that manufactures the video game's platform
  - 'Nintendo' when *platform* is '3DS', 'DS', 'GB', 'GBA', 'GC', 'N64', 'Wii', or 'WiiU'
  - 'Sega' when *platform* is 'DC'
  - 'PC' when *platform* is 'PC'
  - 'Microsoft' when *platform* is 'X360', 'XB', or 'XOne'
  - 'Sony' when *platform* is 'PS', 'PS2', 'PS3', 'PS4', 'PSP', or 'PSV'
- *rating\_everyone* (binary): Indicates if there is not an age restriction for the video game release
  - '1' when *rating* is 'E'
  - '0' when *rating* is not 'E'

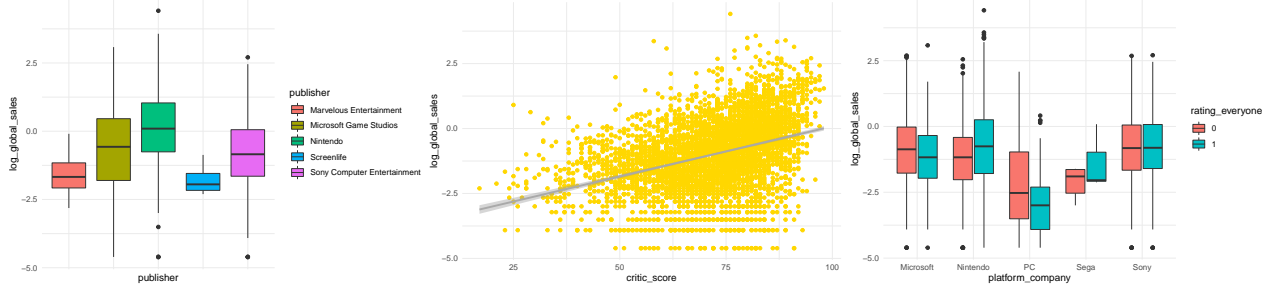
To consider the variable *publisher* into the model, I took a random sample of 50 different publishing companies from the dataset and built a sample dataset to work with. I observed at the distribution of the response variable *global\_sales* and noticed that its distribution is not normal. After applying a logarithmic transformation, the distribution is normal, so I added the following column to the dataset:

- *log\_global\_sales*: Logarithmic transformation of *global\_sales*



A summary of the data variables being analyzed can be found in Appendix 1.1.

For the Exploratory Data Analysis, I plotted every relevant variable versus the response variable *log\_global\_sales*. All of the categorical variables seemed to have different means for the response variable on at least two levels, and the numerical variables seemed to have a positive effect on the response variable. I observed at some interactions between categorical variables (*platform\_company:rating\_everyone*, *platform\_company:genre*, and *genre:rating\_everyone*) and since the distributions seemed to vary I took them into account during the model selection. (For a full EDA, see Appendix 1.2).



## Model

A detailed description of the model used, how you selected the model, how you selected the variables, model assessment, model validation, and presentation of the model results. What are your overall conclusions in context of the inferential problem(s)?

In order to obtain a final model for the response variable  $\log\_global\_sales$  various methods for model selection were tested and interactions between predictors were considered as part of the full model. Since the publishing companies in the sample dataset are a sample of the total publishers available, I included random intercept effects for *publisher* in the final model. The categorical and numerical variables (except for *na\_sales*, *eu\_sales*, *jp\_sales*, and *other\_sales*, since their sum is exactly equal to *global\_sales*) were taken into account for the model selection as predictors. The interaction terms *platform\_company:genre*, *platform\_company:rating\_everyone*, and *genre:rating\_everyone* were considered too.

The final model was selected with a manual stepwise approach in R, using AIC and the conditional  $R\_GLMM$ -squared (conditional R-squared) from the MuMIn package, which is described as “a variance explained by the entire model, including both fixed and random effects” in *r.squaredGLMM* function documentation. The final model’s conditional R-squared is 0.4928372, meaning almost half of the data’s variance is explained by the model.

The variables *platform*, *genre*, *critic\_score\_c*, *critic\_count\_c*, *user\_count\_c*, as well as the interactions *platform:rating\_everyone* and *genre:rating\_everyone* were found to be significant. The variable *rating\_everyone* was added to the model because its interactions had significant levels and improved the model considerably. With an AIC value of 12114, the final model has the following formula:

$$\begin{aligned}
 \log\_global\_sales_{i,j} = & \beta_{(\text{Intercept})} + \gamma_{(\text{Intercept}),j} + \sum_{p \in P} \beta_p (platform\_company_p)_{i,j} + \sum_{g \in G} \beta_g (genre_g)_{i,j} \\
 & + \beta_{rating\_everyone} rating\_everyone_{i,j} + \beta_{critic\_score\_c} critic\_score\_c_{i,j} + \beta_{critic\_count\_c} critic\_count\_c_{i,j} \\
 & + \beta_{user\_count\_c} user\_count\_c_{i,j} + \sum_{p \in P} \beta_{p,rating\_everyone} (platform\_company_p)_{i,j} rating\_everyone_{i,j} \\
 & + \sum_{g \in G} \beta_{g,rating\_everyone} (genre_g)_{i,j} rating\_everyone_{i,j} + \epsilon_{i,j};
 \end{aligned}$$

Where:

$j \in \{\text{Nintendo, 'Microsoft Game Studios', 'Sony Computer Entertainment', Activision, Ubisoft, 'Electronic Arts', 'Konami Digital Entertainment', LucasArts, Atari, 'Namco Bandai Games', Sega, 'Acclaim Entertainment', 'Midway Games', 'Crave Entertainment', Codemasters, 'Marvelous Entertainment', Rondome-dia, 'Midas Interactive Entertainment', 'Tetris Online', Screenlife, 3DO, 'Home Entertainment Suppliers', 'Indie Games', 'PopCap Games', 'Gathering of Developers', 'Oxygen Interactive', 'Milestone S.r.l.', Agatec, 'XS Games', 'Compile Heart', 'Rebellion Developments', 'Media Rings', 'Yacht Club Games', Enterbrain, Microids, Ackstudios, 'Little Orbit', 'Reef Entertainment', 'Kool Kizz', '2D Boy', 'DHM Interactive',$

‘Flashpoint Games’, ‘Iceberg Interactive’, ‘Mamba Games’, ‘bitComposer Games’, ‘Crimson Cow’, ‘FuRyu Corporation’, ‘Blue Byte’, ‘CDV Software Entertainment’, ‘Lighthouse Interactive’}

$P = \{\text{Nintendo, PC, Sega, Sony}\}$

$G = \{\text{Adventure, Fighting, Misc, Platform, Puzzle, Racing, Role-Playing, Shooter, Simulation, Sports, Strategy}\}$

$$\epsilon_{i,j} \sim N(0, \sigma^2) \quad \text{and} \quad \gamma_{(\text{Intercept}),j} \sim N(0, \tau_{(\text{Intercept})}^2)$$

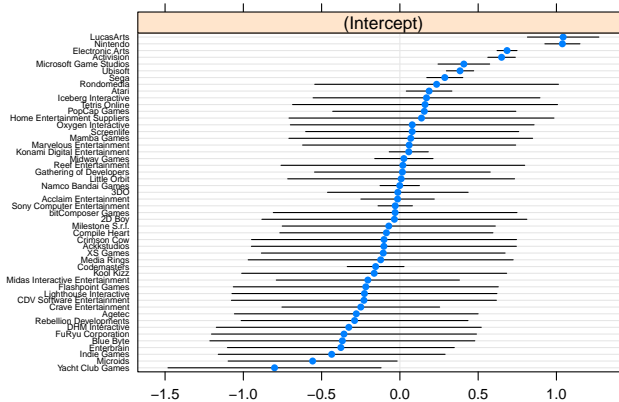
The final model’s fixed coefficients have the following values for every  $\beta$  coefficient:

Table 1: Model’s Fixed Coefficients

	Estimate	t.value	Pr...t..	2.5 %	97.5 %	Sales
(Intercept)	-1.71	-16.01	0.00	-1.93	-1.49	0.18
platform_companyNintendo	0.08	1.31	0.19	-0.04	0.21	1.09
platform_companyPC	-1.44	-18.27	0.00	-1.59	-1.28	0.24
platform_companySega	-0.66	-1.68	0.09	-1.42	0.11	0.52
platform_companySony	0.46	8.80	0.00	0.36	0.56	1.58
genreAdventure	-0.34	-2.99	0.00	-0.56	-0.12	0.71
genreFighting	0.31	3.61	0.00	0.14	0.47	1.36
genreMisc	0.53	6.00	0.00	0.36	0.71	1.71
genrePlatform	0.06	0.58	0.56	-0.14	0.26	1.06
genrePuzzle	-0.20	-0.74	0.46	-0.75	0.34	0.82
genreRacing	0.15	1.71	0.09	-0.02	0.33	1.16
genreRole-Playing	-0.19	-2.52	0.01	-0.33	-0.04	0.83
genreShooter	0.11	1.83	0.07	-0.01	0.22	1.11
genreSimulation	0.43	4.52	0.00	0.24	0.61	1.53
genreSports	0.14	1.45	0.15	-0.05	0.32	1.15
genreStrategy	-0.50	-4.48	0.00	-0.72	-0.28	0.61
rating_everyone1	0.16	1.37	0.17	-0.07	0.40	1.18
critic_score_c	0.02	17.08	0.00	0.02	0.03	1.02
critic_count_c	0.02	18.85	0.00	0.02	0.02	1.02
user_count_c	0.00	14.91	0.00	0.00	0.00	1.00
platform_companyNintendo:rating_everyone1	0.23	2.39	0.02	0.04	0.43	1.26
platform_companyPC:rating_everyone1	-0.04	-0.28	0.78	-0.35	0.26	0.96
platform_companySega:rating_everyone1	0.36	0.51	0.61	-1.01	1.74	1.43
platform_companySony:rating_everyone1	0.13	1.43	0.15	-0.05	0.30	1.13
genreAdventure:rating_everyone1	-0.13	-0.51	0.61	-0.61	0.36	0.88
genreFighting:rating_everyone1	-0.78	-1.48	0.14	-1.80	0.25	0.46
genreMisc:rating_everyone1	-0.23	-1.46	0.14	-0.54	0.08	0.79
genrePlatform:rating_everyone1	-0.15	-0.93	0.35	-0.46	0.16	0.86
genrePuzzle:rating_everyone1	-0.40	-1.23	0.22	-1.03	0.23	0.67
genreRacing:rating_everyone1	-0.26	-1.79	0.07	-0.54	0.02	0.77
genreRole-Playing:rating_everyone1	0.47	2.59	0.01	0.12	0.83	1.60
genreShooter:rating_everyone1	-1.68	-3.92	0.00	-2.52	-0.84	0.19
genreSimulation:rating_everyone1	-0.10	-0.53	0.60	-0.46	0.26	0.91
genreSports:rating_everyone1	-0.22	-1.58	0.11	-0.48	0.05	0.81
genreStrategy:rating_everyone1	0.07	0.27	0.78	-0.42	0.55	1.07

The random intercept effects by publisher or  $\gamma_{(\text{Intercept})}$  random effects are shown in the following plot

(See Appendix 1.3. for a table with the point estimates):



The baseline intercept indicates that a game of no particular publisher, released on a Microsoft Console, of the Action genre, with an age-restriction rating, with critic score of 71.58, reviewed by 30.77 critics and 181.4 users would sell 0.18 million (M) copies worldwide. It can be observed that only 10 out of the 50 publishers have significant (with 95% confidence) random intercept effects: LucasArts (a baseline game would sell 0.52M copies), Nintendo (0.51M), Electronic Arts (0.36M), Activision (0.35M), Microsoft Game Studios (0.27M), Ubisoft (0.27), Sega (0.24M), Atari (0.22M), Microids (0.10M), and Yacht Club Games (0.08M) (the latter two have negative random intercept effects). It is noteworthy that the first 8 publishers release the largest number of videogames and are among the best known video game companies in the world.

As for the fixed effects coefficients, the most significant variables is *critic\_count\_c*. A one-unit increase (31.77 critic reviews in total) would indicate a video game could be expected to sell 2% more units. The other significant variables are *platform\_companyPC* (76% less sales), *critic\_score\_c* (2% more sales), *user\_count\_c* (0.05% more sales), *platform\_companySony* (58% more sales), *genreMisc* (71% more sales), *genreSimulation* (53% more sales), *genreStrategy* (39% less sales), *genreShooter:rating\_everyone1* (additional 81% less sales), *genreFighting* (36% more sales), *genreAdventure* (29% less sales), *genreRole-Playing:rating\_everyone1* (additional 60% more sales), *platform\_companyNintendo:rating\_everyone1* (additional 26% more sales), and *genreRole-Playing* (17% less sales) in order of significance.

All of the VIF values of the model predictors are below 5 with the exception of *rating\_everyone* (See Appendix 1.4. for each individual VIF value). I decided to keep the variable in the model because the interactions between *rating\_everyone* and the categorical variables improve the model significantly. For the most part, the model does not show any serious multicollinearity issues. The model assumptions of linearity, independence, and equal variance seem to be met. The normality assumptions may be a reason to worry about since the Q-Q shows tails on both sides. (See Appendix 1.5.)

## Conclusions

The final model indicates that the main factors that can help us determine how many units a video game will sell globally are the platform manufacturer, the genre of the videogame, the number of users and critics that review the video game on Metacritic, as well as the aggregated critic score it receives. The platforms in which video games sell the most units are made by Sony, belong to the Misc genre, and are rated E for everyone. The better the critic score a video game receives, and the more users and critics reviews it gets, the more units it will sell worldwide.

To improve the model I would start with the collection of data. Building a better web scrapping script I could get complete data for more video games, including recent years. A restriction on the publishing companies to only those that have sold more than a certain amount of units worldwide could also improve the analysis. To avoid the multicollinearity issue with *rating\_everyone* I would use the variable *rating* instead, although the model interpretation and the interaction effects would become way more complicated to interpret, and the model wouldn't be practical or useful.

Although the conditional R-squared value is just a little bit below 0.5, I believe this hierarchical model does represent the reality well enough. The variables that were found to be significant confirm the information observed during the exploratory data analysis, and correspond to my knowledge and understanding of the video game industry. The most well-known publishing companies, best selling platform manufacturers, and most popular genres correspond to the interpretation of the model.

# Appendix

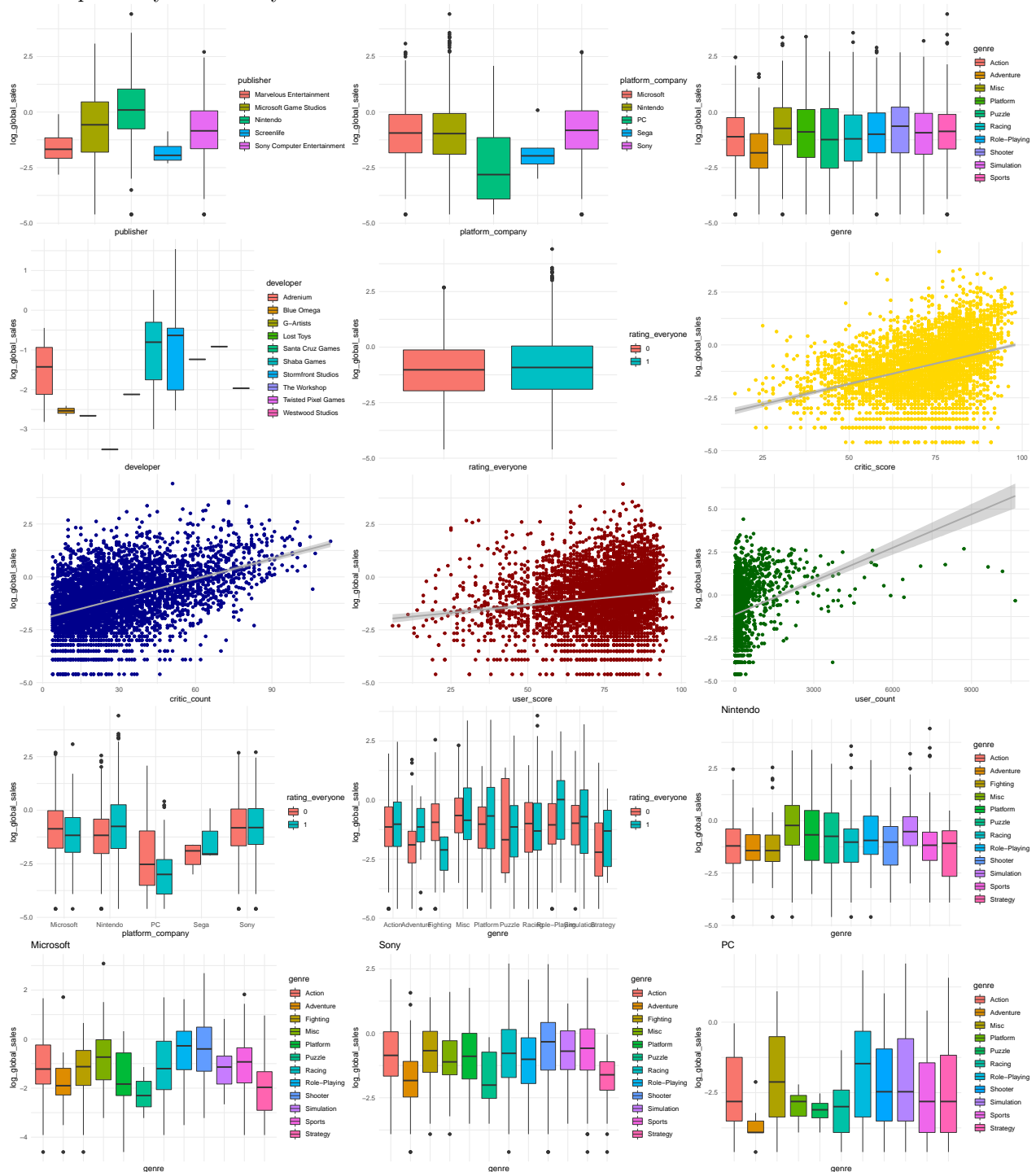
## 1.1 Dataset Summary

```
## [1] "sample_data"
```

```
##
##              name              platform
## Madden NFL 07              : 9 PS2      : 717
## LEGO Star Wars II: The Original Trilogy : 8 X360   : 516
## Need for Speed: Most Wanted              : 8 PS3      : 478
## Harry Potter and the Order of the Phoenix : 7 XB       : 391
## LEGO Indiana Jones: The Original Adventures: 7 PC       : 362
## Madden NFL 08              : 7 Wii       : 306
## (Other)                      :4149 (Other):1425
## year_of_release      genre      publisher
## Min.      :2000      Action      :899 Electronic Arts      : 961
## 1st Qu.:2004      Sports      :793 Ubisoft              : 512
## Median :2007      Shooter      :529 Activision            : 505
## Mean      :2007      Racing      :396 Sony Computer Entertainment: 322
## 3rd Qu.:2010      Role-Playing:324 Nintendo              : 309
## Max.      :2016      Misc        :275 Sega                  : 292
##              (Other)      :979 (Other)              :1294
##      na_sales      eu_sales      jp_sales      other_sales
## Min.      : 0.0000      Min.      : 0.0000      Min.      :0.00000      Min.      :0.0000
## 1st Qu.: 0.0800      1st Qu.: 0.0200      1st Qu.:0.00000      1st Qu.:0.0100
## Median : 0.1900      Median : 0.0800      Median :0.00000      Median :0.0300
## Mean      : 0.4842      Mean      : 0.2998      Mean      :0.08069      Mean      :0.1014
## 3rd Qu.: 0.4800      3rd Qu.: 0.2600      3rd Qu.:0.01000      3rd Qu.:0.0900
## Max.      :41.3600      Max.      :28.9600      Max.      :6.50000      Max.      :8.4500
##
##      global_sales      critic_score      critic_count      user_score
## Min.      : 0.0100      Min.      :17.00      Min.      : 3.00      Min.      : 6.00
## 1st Qu.: 0.1500      1st Qu.:64.00      1st Qu.: 16.00      1st Qu.:66.00
## Median : 0.3700      Median :74.00      Median : 26.00      Median :77.00
## Mean      : 0.9663      Mean      :71.58      Mean      : 30.77      Mean      :73.13
## 3rd Qu.: 0.9300      3rd Qu.:81.50      3rd Qu.: 42.00      3rd Qu.:83.00
## Max.      :82.5300      Max.      :98.00      Max.      :113.00      Max.      :97.00
##
##      user_count      developer      rating
## Min.      : 4.0      Electronic Arts      : 612      E      :1493
## 1st Qu.: 12.0      Ubisoft              : 305      T      :1396
## Median : 29.0      Konami              : 146      M      : 732
## Mean      : 181.4      Sony Computer Entertainment: 107      E10+   : 548
## 3rd Qu.: 96.0      Nintendo              : 85              : 26
## Max.      :10665.0      Codemasters          : 66      AO      : 0
##              (Other)      :2874      (Other): 0
## log_global_sales      critic_score_c      critic_count_c      user_score_c
## Min.      :-4.60517      Min.      :-53.137      Min.      :-26.016      Min.      :-66.5857
## 1st Qu.: -1.89712      1st Qu.: -6.137      1st Qu.: -13.016      1st Qu.: -6.5857
## Median : -0.99425      Median : 3.863      Median : -3.016      Median : 4.4143
## Mean      : -1.01178      Mean      : 1.448      Mean      : 1.749      Mean      : 0.5435
## 3rd Qu.: -0.07257      3rd Qu.: 11.363      3rd Qu.: 12.984      3rd Qu.: 10.4143
## Max.      : 4.41316      Max.      : 27.863      Max.      : 83.984      Max.      : 24.4143
##
##      user_count_c      platform_company rating_everyone
```

```
## Min.    : -169.960   Microsoft:1005    0:2702
## 1st Qu.: -161.960   Nintendo :1130    1:1493
## Median : -144.960   PC       : 362
## Mean    :   7.464    Sega     : 10
## 3rd Qu.: -77.960    Sony     :1688
## Max.    :10491.040
##
```

## 1.2. Exploratory Data Analysis





### 1.3. Random Effects for the Intercept by Publisher

Table 2: Random Effects for the Intercept by Publisher

	gamma	log_global_sales Scale	global_sales Scale
2D Boy	-0.04	-1.74	0.18
3DO	-0.01	-1.72	0.18
Acclaim Entertainment	-0.01	-1.72	0.18
Ackstudios	-0.10	-1.81	0.16
Activision	0.65	-1.06	0.35
Agetec	-0.28	-1.98	0.14
Atari	0.19	-1.52	0.22
bitComposer Games	-0.03	-1.74	0.18
Blue Byte	-0.37	-2.07	0.13
CDV Software Entertainment	-0.23	-1.94	0.14
Codemasters	-0.15	-1.86	0.16
Compile Heart	-0.09	-1.79	0.17
Crave Entertainment	-0.25	-1.96	0.14
Crimson Cow	-0.10	-1.81	0.16
DHM Interactive	-0.33	-2.03	0.13
Electronic Arts	0.68	-1.02	0.36
Enterbrain	-0.38	-2.08	0.12
Flashpoint Games	-0.22	-1.92	0.15
FuRyu Corporation	-0.36	-2.06	0.13
Gathering of Developers	0.02	-1.69	0.18
Home Entertainment Suppliers	0.14	-1.57	0.21
Iceberg Interactive	0.17	-1.54	0.22
Indie Games	-0.44	-2.14	0.12
Konami Digital Entertainment	0.06	-1.65	0.19
Kool Kizz	-0.16	-1.87	0.15
Lighthouse Interactive	-0.23	-1.93	0.14
Little Orbit	0.01	-1.70	0.18
LucasArts	1.04	-0.66	0.52
Mamba Games	0.07	-1.64	0.19
Marvelous Entertainment	0.06	-1.65	0.19
Media Rings	-0.12	-1.83	0.16
Microids	-0.56	-2.26	0.10
Microsoft Game Studios	0.41	-1.30	0.27
Midas Interactive Entertainment	-0.20	-1.91	0.15
Midway Games	0.03	-1.68	0.19
Milestone S.r.l.	-0.07	-1.78	0.17
Namco Bandai Games	0.00	-1.71	0.18
Nintendo	1.04	-0.67	0.51
Oxygen Interactive	0.08	-1.63	0.20
PopCap Games	0.16	-1.55	0.21
Rebellion Developments	-0.29	-1.99	0.14
Reef Entertainment	0.02	-1.69	0.19
Rondomedia	0.23	-1.47	0.23
Screenlife	0.08	-1.63	0.20
Sega	0.29	-1.42	0.24

Table 3: Random Effects for the Intercept by Publisher (continued)

	gamma	log_global_sales	global_sales
Sony Computer Entertainment	-0.03	-1.74	0.18
Tetris Online	0.16	-1.54	0.21
Ubisoft	0.38	-1.32	0.27
XS Games	-0.11	-1.81	0.16
Yacht Club Games	-0.80	-2.51	0.08

## 1.4. Model's VIFs for the Fixed Effects

Table 4: Model's VIFs for the Fixed Effects

	x
platform_companyNintendo	2.38
platform_companyPC	1.90
platform_companySega	1.46
platform_companySony	2.14
genreAdventure	1.39
genreFighting	1.23
genreMisc	1.93
genrePlatform	2.39
genrePuzzle	4.54
genreRacing	2.48
genreRole-Playing	1.52
genreShooter	1.51
genreSimulation	1.66
genreSports	4.78
genreStrategy	1.44
rating_everyone1	11.75
critic_score_c	1.29
critic_count_c	1.59
user_count_c	1.33
platform_companyNintendo:rating_everyone1	3.63
platform_companyPC:rating_everyone1	1.64
platform_companySega:rating_everyone1	1.44
platform_companySony:rating_everyone1	3.29
genreAdventure:rating_everyone1	1.48
genreFighting:rating_everyone1	1.06
genreMisc:rating_everyone1	2.60
genrePlatform:rating_everyone1	3.33
genrePuzzle:rating_everyone1	4.88
genreRacing:rating_everyone1	3.92
genreRole-Playing:rating_everyone1	1.60
genreShooter:rating_everyone1	1.07
genreSimulation:rating_everyone1	1.95
genreSports:rating_everyone1	8.52
genreStrategy:rating_everyone1	1.47

## 1.5. Model Assumptions and Validation

