Master's Thesis
Master Innovation Sciences

Competitive Balance Through Diversity and Technological Ambidexterity

A Case Study of Magic: The Gathering

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Summary

Magic: The Gathering (MTG) is the most played trading card game in the world and has already engaged players for more than 25 years. Regardless of its long standing success, MTG, or similar games, have not been used to explain innovation mechanisms. MTG has the need to innovate to remain competitive within itself, but also to other trading card games. To be competitive within itself, means to have competitive balance, a fair shot at winning for every player involved. Two concepts that make up competitive balance are diversity and technological ambidexterity. Diversity is maintaining an equal distribution of population elements. Technological ambidexterity is the ability for a technology to both have an innovative nature, while also being compatible with the existing population. These concepts, and thus competitive balance, are influenced by three strategies. These strategies are: a change in mixture, a change in absolute values and a change in pattern of mapping. The use of these strategies within MTG and their effects are analysed using longitudinal data of MTG tournaments on four game-modes present within the game. Data on cards and decks were used to measure both diversity and technological ambidexterity. Regression models are estimated for each strategy analysed. The results showed that only the change in mixture strategy had a significant positive effect on competitive balance, whereas the other two strategies did not provide any significant results. These results were partly due to a large correlation between the change in mixture strategy and the other two strategies. This study offers insights in the methods with which (video) games can be used for innovation studies and lays the foundation for future work in this field.

Introduction

Trading card games (TCG's) hold a very prominent position on the international market, in 2017 physical TCG's have more than 25 million monthly active players worldwide, and the number is still growing (Statista, 2017). The most played TCG across the globe is Magic: The Gathering (MTG), with over 20 million players in 2015. MTG was released by Wizards of the Coast in 1993 and is a card game where players collect cards and use their personalized decks to compete against other players (Collectible Card Game, c2020). There were more than 20 billion cards printed between 2008 and 2016 (Wizards of the coast, 2017). The game was acquired by Hasbro in 1999 and is estimated to have accrued more than $500 million in net revenue (Deaux, 2019). As of today, there are over 20,000 unique Magic cards available which can be bought new or traded on second hand markets. MTG is not the only trading card game that spans such a large market. Other examples include: Yu-Gi-oh!, which generated two billion dollars in sales in 2017 (Cowley, 2017), Pokémon, that sold 2.1 billion cards in 2018 (Alphr, 2019) and Hearthstone, a purely digital card game with an estimated market of two billion dollars in 2020 (Minotti, 2018). These examples illustrate that the market for trading card games, and games in other genres, is massive.

To be competitive with other games, games like MTG require an ongoing stream of innovations to keep players interested. MTG accomplishes this by releasing sets of cards each year, with approximately 250 cards each, and by updating rules and restrictions for available cards. These innovations must preserve the competitive balance in the game. Competitive balance within games means that players of equal skill and experience have an equal chance of winning (Adam, 2014). This ensures that multiple strategies or playstyles are viable and that players can compete fairly against other players. This competition is a major factor for enjoyment in (video) games (Vorderer, Hartmann & Klimmt, 2003). In addition, for games in which assets, such as cards, accrue over time, these innovations must give new players a fair chance, without devastating the chances of older generations. An example strategy that MTG applies to conserve competitive balance between newer and older generations is to introduce 'counter plays', where specific cards negate the effects of dominant cards.

From an innovation studies perspective, Innovations within MTG, such as new cards, produce components that allow players to create new technologies, their decks. These decks define the playstyle that a player uses. To preserve competitive balance, card innovations must make sure to maintain the diversity of the components. Diversity is the distribution of population elements with respect to one or more variables (Teachman, 1980). In MTG, these elements refer to different play styles. Cards that stimulate a certain playstyle which are too powerful compared to other cards may negatively influence the diversity, and therefore the competitive balance. Furthermore, diversity can stimulate players to try unseen combinations of cards to surprise opponents.

Maintaining diversity requires an equal distribution of elements, and thus playstyles, over time. The second method to preserve competitive balance is for Wizards of the Coast to be ambidextrous. The concept of ambidexterity has a strong focus on firm level and highlights the scenarios in which organizations have to decide between either exploration or exploitation (Cao, Gedajlovic & Zhang, 2009). These exploration and exploitation tasks are aimed at preserving balance between old and new technologies and is a prominent term in management literature where it is used to guide managers in decision making (O'Reilly III & Tushman, 2011). This so called organizational ambidexterity is used as a building block for the novel concept of technological ambidexterity introduced in this research. While, organizational ambidexterity aims to provide ways to balance innovative (exploration), and supportive (exploitation) activities (Koryak, 2018). Technological ambidexterity focuses on product specific mechanisms to preserve the relative power and usefulness of newer versus older technology generations. This aims to preserve the competitive balance over product generations. To understand how both diversity and technological ambidexterity are influenced over generations, three strategies of technological change described by Saviotti & Metcalfe (1984) are used. These strategies describe how a change in technical characteristics, which refers to the internal structure of the technology, influence the service characteristics, the way with which users use the product. The strategies applied are changes in mixture, changes in absolute values and changes in the pattern of mapping of technical characteristics.

Despite the importance of diversity and ambidexterity in various research fields, the abundance of research on (video) games has paid little attention to these concepts. Most studies are concerned with the impact they exercise on innovation development in other sectors, such as user interface design (Dyck et al, 2003) or running simulations for real life scenarios (Van den Hoogen & Meijer, 2013). Additionally, studies on adoption highlight how cultural differences affect our position regarding games (Weiss, 2008) or how new technologies stimulate video game adoption, such as mobile networking (Liu & Li, 2011). However, these studies are not concerned with preserving a healthy innovative, yet competitively balanced, landscape within a game over time. Thereby, they fail to address the complexity of such a system and what strategies are applied over time to keep players engaged. Furthermore, in (video) games, the current concept of ambidexterity may not suffice. Current literature on ambidexterity does not account for technological interactions among previous generations. In MTG, a shift in focus from explorative to exploitative behaviour or vice versa may greatly impact competitive balance due to these interactions. Therefore, an extension of the concept towards technological ambidexterity is required to account for interactions within the current population of technologies. This leads to the following research question:

What is the effect of the strategies that are implemented to preserve competitive balance over generations in Magic: The Gathering?

The case of MTG is used to illustrate the effects of innovations within a setting where keeping competitive balance over generations is of great importance. MTG is an extremely well documented game. The data on newly released cards and their performance compared to other cards on official tournaments is used to understand how MTG preserves competitive balance over generations by studying the concepts of diversity and ambidexterity.

This thesis builds on the concept of competitive balance in two ways. The first extension is by adding the notion of multiple generations to the competitive balance. It creates a more complex measurement by indicating that competitive balance is not a static concept. The second extension is highlighting that competitive balance over generations is constructed by diversity and technological ambidexterity. Therefore it also widens the application of the diversity and ambidexterity concepts and how these contribute to competitive balance over generations within games. Diversity and ambidexterity are concepts that also diminish the chances of becoming locked-in, which is a phenomenon that affects industries beyond games. While strategies specific to the game are investigated, this study seeks to translate these strategies to methods that can be applied in- and outside the game.

The results of this case study can therefore be of value for actors in different domains where lock-ins are prominent. Strategies to balance the need for incumbent parties to mitigate away from lock-ins, such as a carbon lock-in (Unruh, 2000) or a nuclear reactor type (Cowan, 1990), while not destroying core competencies are provided and may be applied. This research creates a notion of competitive balance over generations that is theoretically applicable in multiple scenarios.

Perhaps, most importantly, understanding how to achieve this competitive balance within games may contribute to player’s enjoyment and may attract more players to the domain.

Theory

2.1 Technology versus service characteristics

To understand how competitive balance over generations is being affected, it is important to highlight that product technologies, such as MTG, are represented by two sets of characteristics: technical and service characteristics. Such a product is simultaneously the output of a producer and the input of a user. On the one hand, the users are mostly interested in the services that a product provides. However, the producer needs to supply these services by a combination of technical characteristics. Technical characteristics thus describes the internal structure of the technology, while service characteristics refer to the services performed for the users of the product (Saviotti & Metcalfe, 1984). These two characteristics are related by a pattern of mapping, this means that the technical characteristics provide services, and that changes in technical characteristics directly or indirectly affect the available services (Frenken, Saviotti & Trommetter, 1999).

In this case, the cards function as technical characteristics and the decks that can be created are service characteristics. While competitive balance over generations is primarily established by the available decks, changes in technical characteristics alter the service characteristics. For MTG, nearly all changes that occur within the service characteristics are produced by additions or changes in ruling among the technical characteristics. Changes such as new cards or restricting the playability of certain cards indirectly alter the decks. The division of MTG in two layers is vital in understanding how changes in either of these layers affects the competitive balance over generations.

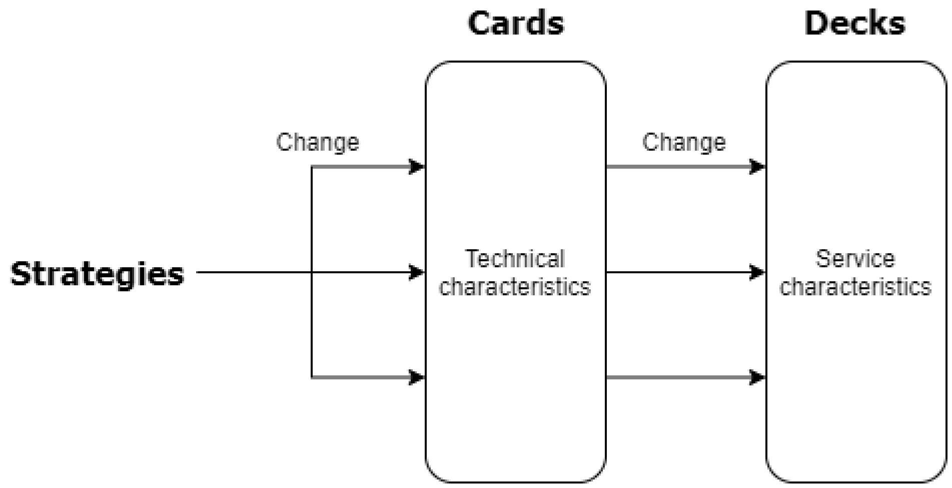

Figure 1: The two layers of MTG and how they are affected

2.2 Competitive balance over generations

As stated in the introduction, a game is competitively balanced when players of equal skill and experience have an equal chance of winning (Adam, 2014). Creating competitive balance in (video) games is two-fold: there must be gameplay balance and fairness (Newheiser, 2009). First, gameplay balance makes sure that your chosen means of playing the game are roughly equivalent to everyone else's, in terms of giving you a fair shot at winning. If gameplay is unbalanced, some strategies, regardless of how well you play, will always have a disadvantage (Newheiser, 2009). Therefore, to maintain competitive balance in a competitive game, the effects of game elements and different playstyles on the game’s outcome must be measured (Jaffe, 2013). This is a time consuming process where game designers must contemplate the effect of each rule on a wide range of possible actions (Jaffe, 2013). Secondly, when games are largely based on skill, fairness aims to create contests that are interesting for players on both sides (Newheiser, 2009). Matching players with other players at the same level so that winning is feasible for both sides. This research will focus on the balance of gameplay, as innovations introduced only affect this balance. Fairness in tournaments is guaranteed by preselecting players that have proven to have sufficient skills to participate. However, imbalance in gameplay may heavily favour certain playstyles and is therefore of greater interest.

Competitive balance is a prominent concept in competitive sectors such as sports leagues and (video) games. It is seen as an important demand for competitive events, since it reflects the uncertainty about the outcomes of such events (Humphreys, 2002). Neale (1964) described this phenomenon as the 'league standing effect', where fan engagement, and thus revenue generating practices such as ticket sales, is directly related to the relative league standings of teams or players within a competition. If the league lacks competitive balance, thus certain teams greatly outperform others, fans will lose interest in the weaker teams, which eventually also leads to a decline in interest for the stronger teams. Competitive balance is therefore seen as a necessity to preserve interest from both contestants and fans.

2.2.1 Diversity

The first part of competitive balance is diversity. It is concerned with an equal representation of elements within a population. Following Stirling (2007), the term diversity consists of three dimensions: variety, balance and disparity. Variety is concerned with the number of different technologies, processes, products, organizations, institutions or strategies in a population of elements. In this case, elements are the number of cards available. Balance relates to the extent in which elements in the population may dominate in size or frequency. Lastly, disparity is a degree of difference between elements in a population. These three dimensions can be used to identify the representation of game elements over time. If there is no equal representation with regards to these technical characteristics, which also implies an uneven representation of service characteristics, there is a lack of diversity, which leads to a decrease of the competitive balance. Diversity is an important driver of technological development.

First, diversity mitigates the chances of becoming locked-in in a particular, suboptimal, technology. Such a lock-in can occur when processes of increasing returns and path dependency are present (Stirling, 1998). These path dependencies that lead to a suboptimal product also decrease the chance for success of the superior alternatives on the long term (Frenken, Hekkert & Godfroij, 2004). Such a lock-in can occur if cards that prove to be dominant are used by many players. Their widespread usage in decks increases the chances of more players using this card in their deck, essentially leading to a lock-in effect. The effects of diversity may diminish the odds of such a card being increasingly present in decks. While a lock-in decreases the competitive balance over time, a lack of equal competitive performance, for example through the existence of a dominant playstyle, also leads to a further decrease in diversity since other contestants will imitate the playstyle due to its success (Jha & Lampel, 2014).

Secondly, Van den Bergh (2008) explains that diversity creates greater potential for creative combinations. These combinations allow for existing elements to be recombined with unused elements to form superior products. This effect influences the possibility for players to search for new combinations of cards that create powerful decks, the service characteristics. Diversity can therefore preserve competitive balance by ensuring that multiple strategies are viable with equal performance.

2.2.2 Technological ambidexterity

Ambidexterity is the method for an organization to exploit existing products while also exploring innovative practices with new products (Andriopoulos & Lewis, 2009). Ambidexterity means that management is aligned and efficient in today's business demands, while also adaptive enough to changes in the environment (Gibson & Birkinshaw, 2004). The concept can be divided into structural[1] and contextual[2] ambidexterity. These divisions have a strong focus on organizational ambidexterity, where alignment focuses on working together toward the same goals, while adaptability aims to reconfigure activities in the organization quickly to meet changing demands in the task environment (Gibson & Birkinshaw, 2004). However, this research aims to use the concept of ambidexterity on a different level of analysis. It creates technological ambidexterity as a novel concept, which is used to view ambidexterity from a technological point of view. Technological ambidexterity is the ability for a technology to both have an innovative nature, while also being compatible with the existing population. The nature of the game creates a need for such a concept, since older generations must not be destroyed by innovative activities. It requires technological innovation along the existing technological trajectory. Technological ambidexterity may shed light on the way that technical and service characteristics are represented in a population, and how they affect the competitive balance.

Methods to achieve ambidexterity are slim. Adler, Goldoftas & Levine (1999) and Siggelkow & Levinthal (2003) both provide various approaches to tackle organizational ambidexterity by respectively identifying four mechanisms and discussing organizational structures that support ambidexterity. Unfortunately, these mechanisms and organizational structures provide no applicability within this domain, as they provide no handles to view and support ambidexterity on a technological level. However, strategies to preserve technological ambidexterity are present in MTG. The most used strategies are introduced in the next paragraph.

2.3 Strategies to influence competitive balance

Saviotti & Metcalfe (1984) describe three[3] theoretical dimensions of technological change that are used as strategies in MTG to influence competitive balance over generations.

2.3.1 Change in the mixture of technical characteristics

The first dimension of technological change is a change in the mixture or balance of technical characteristics. This means that a different usage of available technical characteristics leads to a difference in available service characteristics. For example a new car with a similar engine as a predecessor but a new exterior design. In MTG, a strategy that allows for changes to this mixture is the existence of multiple game-modes, where each game-mode contains a specific set of rules and cards. These game-modes therefore also influence the other two strategies, the absolute values of technical characteristics, namely the number of available cards, and the pattern of mapping, as each game-mode may employ different rules.

Within these game-modes both diversity and technological ambidexterity may differ. However, it is expected that the use of multiple game-modes has a positive impact on the game's overall diversity and technological ambidexterity. The increase in diversity is expected through the much wider variety of cards to choose from, since specific game-modes only allow for specific sets of cards. The default game-mode has the least technological ambidexterity, due to the nature of the game-mode. Adding more game-modes provides an opportunity to be more ambidextrous than the default game-mode. This opportunity leads to the expectation that players will tend to use both old and new cards in their deck. This leads to the following hypotheses:

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[1] Structural ambidexterity explains how an organization allows for the coexistence of the paradoxical exploratory and exploitative efforts at different locations where the focus can be entirely on either alignment or adaptability (Jansen, Tempelaar, Van den Bosch & Volberda, 2009).

[2] Contextual ambidexterity is the capacity to simultaneously demonstrate alignment and adaptability across an entire organization.

[3] There are 2 other dimensions not mentioned here (change in mixture or balance of service characteristics and change in absolute values of service characteristics). These dimensions are not directly altered by strategies present in MTG and therefore not applied.

Hypothesis 1a: The availability of multiple mixtures of technical characteristics increases the game's diversity compared to the default.

Hypothesis 1b: The availability of multiple mixtures of technical characteristics increases the game's technological ambidexterity compared to the default.

2.3.2 Change in absolute values of technical characteristics

The second dimension of technological change is the change in absolute values of technical characteristics. A change in absolute values means that there is an addition or removal related to a technical characteristic, for example adding a gear to a car's gearbox. There are two methods that change the absolute values of cards in MTG. The first method is the routinized addition of new cards. Each year, a similar number of new cards are added to the game, via the release of new sets of cards. This directly alters the amount of technical characteristics, but also provides new possibilities to create service characteristics. The second method of changing the absolute values of technical characteristics is the banning of cards, which may be needed if released cards too strongly impact the competitive balance. However, this is not a preferred strategy, since this destroys the value of such cards.

It is expected that a higher availability of cards, thus technical characteristics, leads to a higher diversity and technological ambidexterity. The increase in diversity is expected since more cards open up more opportunities for new combinations, which are able to match power levels of previous decks. These new combinations are also expected to lead to more technological ambidexterity since cards from a number of years can be used in these new decks. On the other hand, cards that prove to be too powerful and are banned from play also lead to an increase of both diversity and technological ambidexterity. While this effect may seem counterintuitive, since it decreases the absolute values of technological characteristics, it is expected due to the reasons of banning cards. Cards that are extremely powerful will require all players to use these cards in order to have a fair chance at winning, taking away other possible combinations and thus decreasing the diversity. Removing such a card can therefore open up the possibilities for using a larger variety of strategies. Technological ambidexterity decreases when a card is picked by every player, since it does not create an equal division of new and old cards that are used. Removing such a card therefore is expected to increase the technological ambidexterity. This leads to the following hypotheses:

Hypothesis 2a: An increase in available technical characteristics leads to an increase in diversity.

Hypothesis 2b: An increase in available technical characteristics leads to an increase in technological ambidexterity.

Hypothesis 2c: An increase in banned technical characteristics leads to an increase in diversity.

Hypothesis 2d: An increase in banned technical characteristics leads to an increase in technological ambidexterity.

2.3.3 Change in the pattern of mapping

The third dimension is a change in the pattern of mapping. The pattern of mapping is the method with which technical characteristics influence the service characteristics. It also explains which technical characteristics have an effect on which service characteristics. For example, adding a different seat to a car influences the comfort of passengers in the car. In MTG, changes in pattern of mapping is achieved by updating rules and restrictions. Rules are kept track of in the 238 page long 'Magic: The Gathering Comprehensive Rules' book, which is updated when necessary (Wizards of the coast, c2020).

It is expected that a year in which more changes in the pattern of mapping also result in an increase in diversity and technological ambidexterity. Rules are implemented when scenarios occur which are not desirable. These scenarios often break competitive balance, or create frustrating situations for players. The goals with which new rules are implemented are therefore expected to be in line with improving or restoring competitive balance. Thus increasing both diversity and technological ambidexterity. This leads to the second hypothesis:

Hypothesis 3a: An increase in the changes in the patterns of mapping leads to an increase in diversity.

Hypothesis 3b: An increase in the changes in the patterns of mapping leads to an increase in technological ambidexterity.

These strategies highlight that the addition, removal or change in use of technical characteristics may be three important mechanisms in increasing competitive balance.
This leads to the following conceptual model:

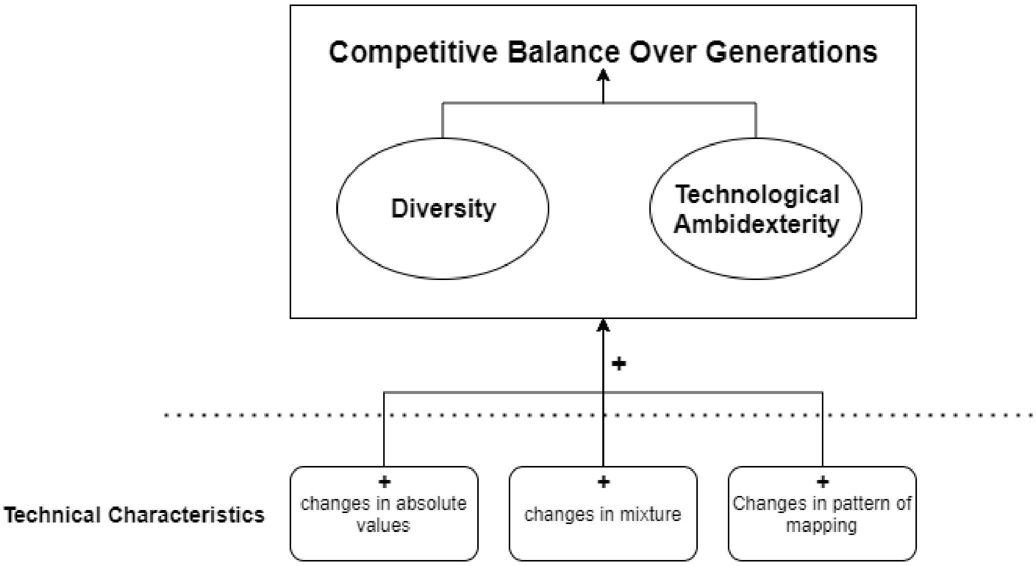

Figure 2: The conceptual model

Methods

3.1 Research design

This research employs a correlational quantitative design by means of a case study of the trading card game Magic: The Gathering.

3.2 Case selection

Magic: The Gathering, a game released in 1993 which is still popular to this day, has undoubtedly withstood the test of time. It has proven that it's able to continuously engage existing players, while also attracting new ones. On a different scale, this case therefore adheres to a very classical innovation problem; the need to both keep, and attract, adopters of products or innovations. While the specific methods with which the players of Magic: The Gathering are tempted to keep returning may be different, their underlying mechanisms and effectiveness could help further develop more widespread innovation literature.

MTG is an extremely well documented game, which allows for precise analysis of the dynamics in competitive balance over generations. This thesis analyses quantitative longitudinal data of MTG tournaments and how the applied strategies influenced the competitive balance over generations. These tournaments are of interest due to two reasons. Firstly, they highlight a high level of selection of cards and playstyles. This selection is created through vigorous competition where only the best players using the best combinations of cards are present at these tournaments. Secondly, these tournaments legitimize the use of particular cards or playstyles. Furthermore, MTG can be played through a total of 16 of game-modes, which all employ differences in technical and service characteristics that can be identified. However, four game-modes are used in this research. These game-modes are: Standard, Vintage, Legacy and Modern[4]. These game-modes are selected since they are a so-called 'constructed format' which adhere to the following rules: A deck needs a minimum of sixty cards, there is no maximum deck size as long as you can shuffle your deck unassisted and there can be up to fifteen cards in your sideboard. These deck structures can differ greatly in between other game-modes, which makes it more difficult to properly measure the effect of changes in technical characteristics.

3.3 Data collection

Three main sources are used: MTGJSON[5], MTG Top 8[6] and MTG Wiki[7].

MTGJSON is an open-source project that catalogs all MTG cards in a portable format. Using an aggregation process they fetch data between multiple resources and approved partners, and combine all this data into various JSON and CSV files that are available for download from their website. Two downloadable files are used: the first being a dataset of all cards[8] and the second being a setlist dataset. The cards dataset provides an encompassing list of each card that has ever existed in the game. Each card is assigned to a row and contains a large variety of card specific variables. The complete list of variables is found in Appendix 1. The setlist dataset provides an overview of the sets of cards that have been released over the years. it provides crucial information such as the code for the set, its full name and its release date. The variables available for this setlist are found in Appendix 2.

[4] Standard and Vintage were previously called type 2 and type 1 respectively
[5] https://mtgjson.com/
[6] https://www.mtgtop8.com/index
[7] https://mtg.gamepedia.com/Main_Page
[8] This cards.csv file can be found in the 'AllPrintingsCSVFiles' collection

MTG Top 8 keeps track of the top eight performing decks played at all major tournaments, which span all official game-modes. MTG Top 8 tracks the amount of players for each tournament, information on cards played in each deck and deck performances. Each deck is downloaded as a text file which contains both the name of a card, and the frequency of appearance in that deck. The top eight performing decks for the most populated tournament, for every year, across the four game-modes are downloaded for every available year. Table 1 shows the number of decks available for each game-mode.

	Game-mode	Available Years	Number Of Decks
1	Standard	1998 - 2019	176
2	Legacy	2005 - 2019	120
3	Vintage	2005 - 2019	120
4	Modern	2012 - 2019	64

Table 1: The number of decks collected for each game-mode

The MTG Wiki contains information on all aspects of MTG. It is used as a source of information regarding card availability. This refers to the timeframe in which certain sets of cards are available for use, but also to the list of banned or restricted cards for each individual game-mode. This historical data of MTG highlights when changes were introduced and is used to correctly filter the complete card dataset obtained from MTGJSON.

Data from the three sources is combined to create meaningful datasets that allow for measurement and analysis of both diversity and technological ambidexterity. The following data preparation strategy is used for each game-mode. First, a new variable 'release year' is added to the setlist dataset. This variable is created by altering the 'release date' variable to only contain the year instead of the specific date. Secondly, the cards and setlist dataset are joined by 'set code', a variable that both the card and setlist dataset contain. This adds the setlist variables to the cards dataset for each row (card). Third, using information from MTG wiki, new datasets are created that only contain the cards that were available for use at a specific time for a specific game-mode. This is done by filtering on release year and set codes. Next, the decks downloaded from MTG Top 8 are edited to adhere to a more analysis friendly format (see Appendix 3 for the specific format). Lastly, the deck text files are imported and joined with their respective game-mode and year datasets. This results in a situation where every deck is available as a dataset with all the variables previously available in the cards dataset.

3.4 Measurement and analysis

Competitive balance consists of two dimensions: diversity and technological ambidexterity.

3.4.1 Diversity

Diversity is measured by applying the measurements of its underlying concepts: variety, balance and disparity. These three concepts are all measured for each year and game-mode. Where variety and balance are measured on both the technical and service level, and disparity is measured on service level. This leads to four measurements that are used together to understand the diversity: card variety, card entropy, deck variety and deck entropy.

First, the variety of cards, thus technical characteristics, is directly measured through counting the total number of unique cards in the eighth decks analysed for each individual year and game-mode. Variety of decks is measured using the disparity concept and further elaborated upon in its respective section.

Balance is the representation of different cards and decks, and is thus measured on both technical and service level. The addition of balance on both technical and service level gives a more complete understanding of the diversity concept. While two varieties (technical or service level) may be the same, one of the varieties may have a better balance and is therefore more diverse. It is commonly measured using the entropy statistic, which measures the randomness of a population (Van Rijnsoever, Van Den Berg, Koch & Hekkert, 2015). Entropy takes balance and variety into account and is measured using the entropy statistic introduced by Shannon (1948). Given a discrete random variable X, with possible outcomes $x_1,...,x_n$, which occur with probability $P(x_1),...,P(x_n)$, the entropy of X is defined as:

$$H(X) = -\sum_{i=1}^{n} P(x_i) Log P(x_i)$$

Where ∑ denotes the sum over the variable's possible values.

By analysing the total set of cards and decks for a specific year, the entropy statistic is used to highlight the evenness of that card and deck population. A higher entropy score indicates that the population is more evenly distributed, and therefore, more balanced.

Lastly, disparity is measured on service level. Here, disparity is used as a degree of difference between decks using the names of the cards used in the decks, where decks are perfectly dispersed if they do not have any overlapping cards. It is not measured on card level as this would require in depth analysis of the in-game functionality of cards which is out of the scale of this research. For each year, a dataset is created showing which, and how many, cards are used in any of the eight decks. Where cards not used in a deck obtain a value of zero. This dataset containing the frequency of each card in each deck was analysed using a principal component analysis (PCA). The goal of the PCA is to detect commonalities of underlying principles that come from combining different cards. This leads to the service level disparity which shows how different the analysed decks are. Using so-called cut-off points of 0.4, the PCA is used to determine how many components, which are decks, are needed to explain the entire dataset. The results of the PCA are also plotted to gain a more visual representation of how the eight decks are dispersed. This dispersion is used to calculate both the deck variety and deck entropy. First, deck variety is the number of components that are identified as required to explain the dataset. Secondly, deck entropy is calculated using the Shannon entropy formula as explained above. When many decks overlap, it indicates a low degree of disparity, and results in a low deck variety which negatively influences the competitive balance. Appendix 4 shows a result of such a PCA for clarification.

3.4.2 Technological ambidexterity

Technological ambidexterity in MTG is a measure that expresses how well released cards fit into the current state of the game. Each tournament analysed contains 480[9] cards (eight decks of 60 cards) where each card has a certain release year. Technological ambidexterity is expressed by the division of cards among the available release years, where perfect ambidexterity is achieved when each release year is represented equally. To achieve this, the release year of every card played in every year and game-mode is stored. With each year, the pool of available cards is expanded through the addition of new cards. However, in the standard game-mode, players are only allowed to play with cards released in that same year. This results in a situation where there is no ambidexterity in this game-mode. Therefore, this game-mode is used as a reference category to which the other game-modes (Vintage, Legacy and Modern) are compared, as they do allow for cards from many generations to be played. In those cases, the usefulness of newly released cards can be compared against their older counterparts. If new cards take up a too large share within the eight decks, they might be too powerful which decreases competitive balance. Vice versa, if

[9] Some years have a few more due to the nature of certain cards

newly released cards do not appear in these game-modes, they are likely too weak, which also decreases competitive balance. Appendix 5 shows an example of such a division for clarification.

3.5 Applied strategies

3.5.1 Change in the mixture of technical characteristics

The change in mixture or balance within MTG refers to the game-modes in which players are able to compete. The Standard game-mode is the longest existing game-mode, which is played with a limited number of sets released every year. The Vintage game-mode was created in 1995 and allows cards from *all* card sets and does not allow the banning of cards due to power reasons[10]. Next, the Legacy format was created in 2004 as an answer to the Vintage game-mode. In Legacy, cards from *all* card sets are allowed but it *does* allow the banning of cards due to power reasons. Lastly, Modern is created as an independent game-mode in 2011 and features a specific list of sets starting from 2003. The availability of tournament data has resulted in 22 Standard tournaments, 15 tournaments from both Vintage and Legacy and eight for the Modern game-mode.

3.5.2 Change in absolute values of technical characteristics

The absolute values of technical characteristics in MTG are the number of cards a player is allowed to choose from for any given tournament. These values, and the changes of these values, are built up from two components: the cards available in the sets that are allowed for each specific tournament and the list of cards that are banned. The number of cards allowed through the sets of cards varies greatly between game-modes. Where Vintage and Legacy allow for the most cards to be chosen, followed by Modern. Standard has by far the least amount of available cards, which is due to the very nature of the game-mode.

3.5.3 Change in the pattern of mapping

Changes in rules or restrictions change the way which decks, the service characteristics, are built. In MTG keeping track of which cards are game-breaking and therefore either required to be banned or restricted are the most important changes in pattern of mapping and is measured through two variables. First, the number of cards that have been banned in the current state of the game but were used in previous years is mapped. Secondly, the number of cards that are newly banned each year is shown. These metrics highlight what direct effects occur after the banning of cards that were negatively impacting the game. The use of restrictions (allowing only one of the same card to be played in a deck instead of the usual four) is only truly applicable in one scenario, which is in the Vintage versus Legacy formats. Many of the cards that are banned in the Legacy game-mode, are restricted in the Vintage game-mode. Allowing for a very unique scenario where extremely powerful cards are allowed to be played. Due to this specific case, no quantitative metrics are applied for this event, however the effect of this is elaborated upon in the results section.

Table 2 and 3 give the descriptive statistics and the correlation matrix for the variables used in the analysis.

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[10] There are a few exceptions. Furthermore, cards can be banned from this game-mode if the cards were designed for different formats or if they are removed from the entire game due to depictions of racism.

	Variable	N	Mean	Standard deviation	Minimum	Maximum
1	(DV) Card entropy	60	4.16	0.27	3.38	4.67
2	(DV) Deck entropy	60	1.15	0.25	0.56	1.73
3	(DV) Technological Ambidexterity	60	1.28	26.85	-40.64	66
4	(IV) Available cards	60	8927	6406.79	973	20486
5	(IV) Banned cards	60	18.63	21.9	0	54
6	(IV) Banned cards played	60	6.68	11.05	0	44
7	(IV) Cards banned in a year	60	1.13	1.92	0	8
8	(IV) Game-mode	60	NA	NA	NA	NA

Table 2: Descriptive statistics of the variables used in the analysis

Correlation Matrix

	Card Entropy	Deck Entropy	Technological Ambidexterity	Availabe Cards	Banned Cards	Banned Cards Played	Cards Banned In A Year
Card Entropy	1	0.399	0.622	0.711	0.540	0.443	-0.127
Deck Entropy	0.399	1	0.212	0.129	0.516	0.508	0.209
Technological Ambidexterity	0.622	0.212	1	0.766	0.570	0.460	-0.007
Available Cards	0.711	0.129	0.766	1	0.677	0.493	-0.108
Banned Cards	0.540	0.516	0.570	0.677	1	0.806	0.409
Banned Cards Played	0.443	0.508	0.460	0.493	0.806	1	0.238
Cards Banned In A Year	-0.127	0.209	-0.007	-0.108	0.409	0.238	1

Table 3: Correlation matrix of the variables used in the analysis

3.6 Analysis

The three strategies are analysed using linear mixed effects models. These models are an extension of the linear model which allow for a way to deal with repeated measures. In each of the models, the years in which the tournaments are held are these repeated measures and are used to create random intercepts as opposed to static intercepts which regular linear models provide. In every model, the two underlying balance measures of diversity (card entropy and deck entropy) and the ambidexterity scores are used as dependent variables.

First, changes in mixture are analysed by using the game-modes as independent variables to highlight the effects on both diversity and technological ambidexterity across game-modes. These three models are used to either support or reject hypotheses 1a and 1b.

Secondly, the effects of changes in the absolute values of technical characteristics across all game-modes are analysed. In these models, the number of available and banned cards are used as independent variables. These three models are used to either support or reject hypotheses 2a, 2b, 2c and 2d.

Lastly, models are created to find the effects on diversity and technological ambidexterity through changes in the pattern of mapping. The independent variables used in these models are the banned cards played and cards banned in a year. These models are used to either support or reject hypotheses 3a and 3b.

To achieve the most reliable and easy to understand models, two approaches were used for every model. First, the dependent variables are standardized to help comparisons. Secondly, the log values of the continuous independent variables were used in order to create a more normalized dataset.

These statistical models are accompanied by visualisations to further accentuate how these variables have developed over time. These regressions and visualizations help understand what strategies are the most vital in creating competitive balance over time.

Results

Firstly, a more in-depth explanation regarding the three different strategies for changing technical characteristics and how they are correlated with each other is given. Secondly, the regression models estimating the effects of each strategy on the diversity and technological ambidexterity is shown.

While the three strategies are presented as separate occurrences, they are heavily linked to one another within the context of MTG, whereas this in other scenarios might not be the case. This is primarily due to the nature of the game-modes which are available in MTG. The game-modes define what cards players of the game are allowed to use to create their decks. This means that the two other strategies are directly affected by the game-modes. It both defines which sets of cards players are available for use, the absolute value of technical characteristics, and the specific rules that apply, which refers to the mapping of technical characteristics. It is important to understand that these two strategies can occur within a game-mode, but they are mostly affected by the differences between game-modes. To deal with these interlinkages the two other strategies are also tested and controlled for using game-mode to properly analyse these effects.

4.1 Effects on diversity and technological ambidexterity

The regression models are visualized in a way where each model indicates the effects of the independent variables (left) on one dependent variable (top). Models are read from top to bottom, where every column starts with the estimators for each independent variable. Followed by the number of years in the analysis, the random variance and standard deviation of these years, the R^2 score, the number of observations and model fit measures.

4.1.1 Change in mixture

Table 4 presents the results of testing hypotheses 1a and 1b.

Results change in mixture

	Dependent variable:		
	Card entropy	Deck entropy	Technological Ambidexterity
	Model 1	Model 2	Model 3
Game-mode Legacy	1.352***	1.040***	1.640***
	(0.195)	(0.253)	(0.193)
Game-mode Modern	2.109***	0.915***	1.773***
	(0.244)	(0.315)	(0.238)
Game-mode Vintage	1.422***	-0.578**	1.719***
	(0.195)	(0.253)	(0.193)
Constant	-0.989***	-0.233	-1.076***
	(0.133)	(0.168)	(0.123)
Number of years	22	22	22
Variance (Year)	0.06	0.063	0
sd (Year)	0.244	0.25	0
R-squared	0.613	0.401	0.672
Observations	60	60	60
Log Likelihood	-57.605	-71.142	-54.001
Akaike Inf. Crit.	127.211	154.284	120.002
Bayesian Inf. Crit.	139.777	166.850	132.568
Note:			*p**p***p<0.01

Table 4: The results of three regression models concerning the change in mixture strategy

The models have R^2 values of 0.613, 0.401 and 0.672 respectively, which is very good. The models do not heavily suffer from heteroscedasticity and the distribution of the residuals approach normality. All three models have random variance scores very close to zero, indicating that the random effects are negligible. This means that years did not affect the outcome of these models.

Model one and two, which show the results of testing hypothesis 1a, shows that each of the three game-modes have a statistically significant positive relationship with card entropy and deck entropy compared to the Standard game-mode, which is used as the reference category. There is one exception, estimating a negative relationship. The Vintage game-mode is negatively related to deck entropy compared to Standard, indicating a decrease in deck entropy, and thus diversity. This negative relationship is caused by the so-called "Power Nine" [11]. Regardless of this relationship, the results support the diversity argument of hypothesis 1a. Meaning that the overall diversity increases by introducing multiple game-modes as opposed to only using the Standard game-mode. Model three shows the results of testing hypothesis

[11] https://mtg.gamepedia.com/Power_Nine

1b. The Standard game-mode has no technological ambidexterity by definition, since it only allows for cards from that particular year to be played. Therefore, this model shows whether the other game-modes differ statistically significant from zero (0). The model indicates that Legacy, Modern and Vintage all have a statistically significant improvement over zero. This indicates that multiple game-modes lead to an increase in technological ambidexterity over the reference game-mode, therefore supporting hypothesis 1b.

The negative relationship towards deck entropy for the Vintage game-mode can be explained by the so-called "Power Nine". These nine cards are so incredibly powerful that they are only allowed in the Vintage game-mode, where they are restricted. However, they appear in every single deck played at a competitive level which drives the disparity between the decks down, thus also resulting in a lower deck entropy. The boxplot in figure 3 also shows this discrepancy between Vintage and the other game-modes.

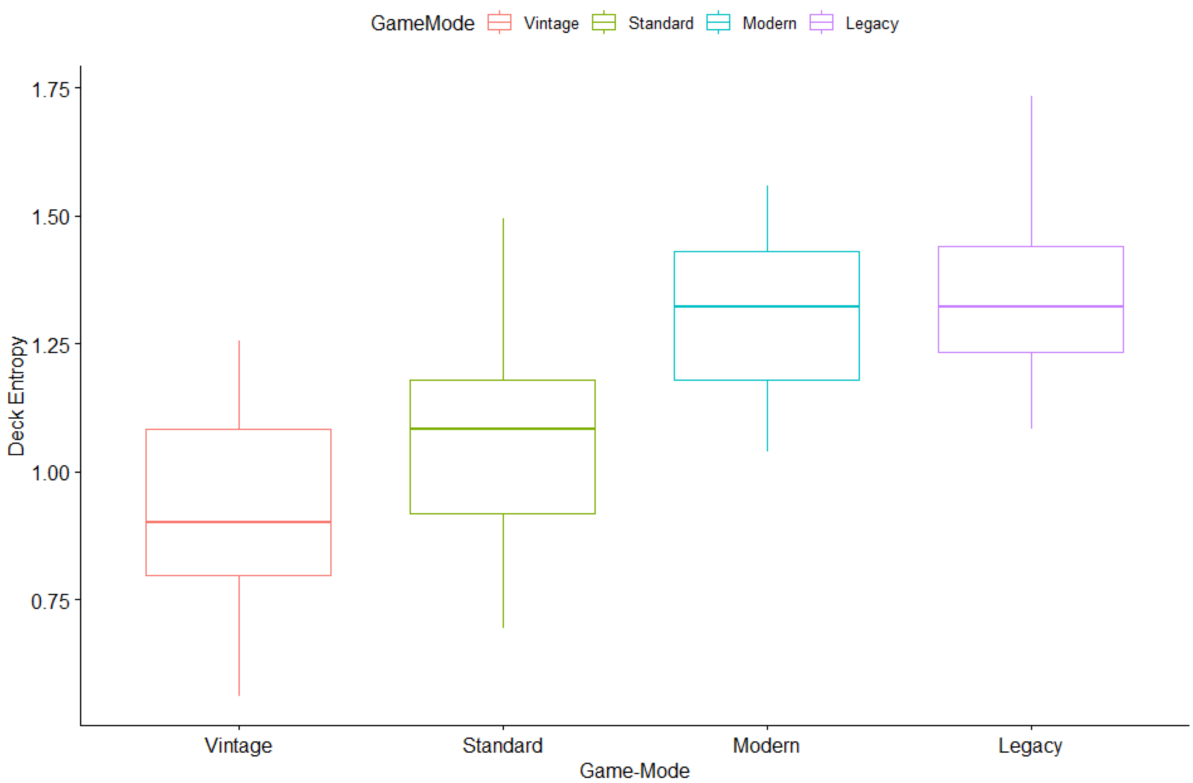

Figure 3: Boxplot showing the deck entropy distribution for each of the game-modes

4.1.2 Change in absolute values

Table 5 presents the results of testing hypotheses 2a, 2b, 2c and 2d.

Results change in absolute values

	Dependent variable:					
	Card entropy	Deck entropy	Technological Ambidexterity	Card entropy	Deck entropy	Technological Ambidexterity
	Model 4	Model 5	Model 6	Model 7	Model 8	Model 9
Number Of Available Cards	0.577***	-0.381***	0.650***	-0.080	-0.529	-0.770**
	(0.111)	(0.127)	(0.105)	(0.389)	(0.485)	(0.328)
Number Of Banned Cards	0.076	0.522***	0.062	-0.116	0.065	0.001
	(0.077)	(0.088)	(0.073)	(0.160)	(0.203)	(0.145)
Game-mode Legacy				1.929*	2.006	3.361***
				(1.035)	(1.293)	(0.874)
Game-mode Modern				2.607***	1.725	3.258***
				(0.898)	(1.126)	(0.774)
Game-mode Vintage				1.696*	0.559	3.442***
				(0.901)	(1.124)	(0.758)
Constant	-5.161***	2.252**	-5.753***	-0.341	3.583	4.530*
	(0.871)	(0.991)	(0.820)	(2.835)	(3.536)	(2.384)
Number of years	22	22	22	22	22	22
Variance (Year)	0.052	0.08	0.012	0.046	0.08	0
sd (Year)	0.227	0.282	0.111	0.215	0.235	0
R-squared	0.499	0.36	0.586	0.612	0.405	0.695
Observations	60	60	60	60	60	60
Log Likelihood	-67.524	-75.221	-62.626	-58.288	-70.994	-52.493
Akaike Inf. Crit.	145.049	160.442	135.253	132.576	157.989	120.987
Bayesian Inf. Crit.	155.520	170.914	145.725	149.331	174.743	137.742
Note:						*p**p***p<0.01

Table 5: The results of six regression models concerning the change in absolute values strategy

These six models all test the same four hypotheses. Model 4, 5 and 6 only use the independent variables related to the strategy, which means it tests the hypotheses across game-modes. Model 7, 8 and 9 also control for game-mode due to the correlation between game-mode and the changes in absolute values, which means it tests the hypotheses within game-modes. Model four and five have an R^2 value of 0.499 and 0.36, which is good. Model six scores higher at 0.586, which is very good. The three models do not heavily suffer from heteroscedasticity and the distribution of the residuals approach normality. Furthermore, variance inflation factors were 1.82, 1.81 and 1.84 respectively for Model 4 and 5, 6, which is acceptable. There is also a close to zero random variance which indicates that the year of analysis does not influence hypothesis testing.

Model 7, 8 and 9 all see an increase in R^2 value to 0.612, 0.405 and 0.695, all indicating a very good model fit. However, all three models suffer from immense variance inflation factors. With scores ranging from 9.52, which are barely acceptable, up to 160.59, which is unacceptable. These scores are introduced by using game-mode as a control variable since they largely influence the number of available cards and how many cards are banned. The random variance is still close to zero, indicating that values are not affected by. An alternative regression where there has been controlled for the large variation inflation factors is shown and explained in Appendix 7. The models in Appendix 7 show that even with acceptable variation inflation factors, the effect of the number of available cards and the number of banned cards remain relatively the same. This further cements the statement that hypotheses 2a, 2b, 2c and 2d are not supported by these results.

Models 4 and 5 test hypotheses 2a and 2c. It can be seen that the number of available cards has a statistically significant positive effect on card entropy and a negative effect on deck entropy. The number of banned cards only has a statistically significant positive effect on deck entropy. However, when controlling for game-mode in model 7 and 8 it can be seen that the effects visible in model 4 and 5 are not present anymore. Only the game-mode has a significant impact on the card and entropy. Considering both models, hypothesis 2a and 2c are not supported. Model 6 tests hypotheses 2b and 2d. The model shows a significant positive relationship between number of available cards and technological ambidexterity and a non-significant positive relationship between banned cards and technological ambidexterity. When controlling for game-mode in model 9, it can be seen that these relationships from model 6 change. The significant positive relationship between number of available cards and technological ambidexterity is now a significant negative relationship. Since a positive relationship was expected, hypotheses 2b and 2d are also not supported.

The lack of support for all four hypotheses requires exploration of individual game-modes. With regards to hypotheses 2a and 2c, it can be seen that the entropy increases between game-modes, where other game-modes have more available cards than the standard game-mode. This creates the idea that more cards lead to more diversity. However, when investigating the three game-modes (Legacy, Vintage and Modern) where the number of available cards rises every year with the addition of new cards, adding more cards does not result in a rise in entropy or technological ambidexterity. Appendix 8 shows a more visual approach to this phenomenon. This shows that the fact of having more technical characteristics (cards) does not lead to an increase of diversity and technological ambidexterity. Hypotheses 2b and 2d are also not supported by the data. This is also due to the fact that the number of banned cards only contain very minor shifts for each game-mode which can be seen in Appendix 6. While intuitively the removal of powerful cards by banning them would require players to look for alternatives, thereby increasing diversity and technological ambidexterity, the data is not able to show such an effect.

4.1.3 Change in mapping

Table 6 presents the results of testing hypotheses 3a and 3b.

Results change in pattern of mapping

	Dependent variable:					
	Card entropy	Deck entropy	Technological Ambidexterity	Card entropy	Deck entropy	Technological Ambidexterity
	Model 10	Model 11	Model 12	Model 13	Model 14	Model 15
Banned Cards Played	0.354^{***}	0.349^{***}	0.345^{***}	-0.161	-0.059	0.092
	(0.083)	(0.081)	(0.085)	(0.123)	(0.162)	(0.119)
Cards Banned In A Year	-0.362^{**}	0.161	-0.182	-0.185	0.028	0.116
	(0.173)	(0.172)	(0.177)	(0.129)	(0.170)	(0.123)
Game-mode Legacy				1.747^{***}	1.180^{**}	1.419^{***}
				(0.352)	(0.462)	(0.343)
Game-mode Modern				2.651^{***}	1.075^{*}	1.464^{***}
				(0.430)	(0.566)	(0.423)
Game-mode Vintage				1.331^{***}	-0.563^{**}	1.780^{***}
				(0.207)	(0.272)	(0.205)
Constant	-0.168	-0.417^{***}	-0.249	-0.883^{***}	-0.249	-1.143^{***}
	(0.154)	(0.157)	(0.157)	(0.150)	(0.197)	(0.142)
Number of years	22	22	22	22	22	22
Variance (Year)	0	0.057	0	0.038	0.067	0
sd (Year)	0	0.239	0	0.196	0.259	0
R-squared	0.247	0.271	0.22	0.634	0.394	0.673
Observations	60	60	60	60	60	60
Log Likelihood	-79.595	-78.925	-80.613	-58.028	-72.839	-55.661
Akaike Inf. Crit.	169.189	167.850	171.225	132.056	161.677	127.323
Bayesian Inf. Crit.	179.661	178.322	181.697	148.811	178.432	144.077
Note:						*p**p***p<0.01

Table 6: The results of six regression models concerning the change in pattern of mapping strategy

These six models all test hypotheses 3a and 3b. Model 10, 11 and 12 only use the independent variables related to the strategy, which means it tests the hypotheses across game-modes. Model 13, 14 and 15 also control for game-mode due to the correlation between game-mode and the changes in pattern of mapping, which means it tests the hypotheses within game-modes. Model 10,11 and 12 have an R^2 value of 0.247, 0.271 and 0.22, which is good. The distribution of the residuals of all three models do approach normality, but less than previous models that were created. Furthermore, variance inflation factors were 1.06 and 1.07 which is acceptable. Random variance is zero or close to zero for all three models. Indicating once again that the analysis is not affected by year.

Also taking game-mode into consideration in model 13, 14 and 15, they all see an increase in R^2 values. They are respectively 0.634, 0.394 and 0.673, which are very good. The models all are relatively homoscedastic and the residuals approach normality. The variance inflation factors range between 1.22 and 5.95. Values below ten are generally seen as acceptable, so while the variance inflation factors increased, they are still within acceptable terms (O'brien, 2007). None of the models are affected by random variance.

Model 10 and 11 test for hypothesis 3a. The model indicates a significant positive relationship, between the number of cards that were banned which are currently banned and the entropy measures. The number of cards banned in a year has a significant negative relationship with card entropy. Model 13 and 14 however show that these effects become non-significant with the introduction of game-modes as a control variable. These models paint a very similar picture to Models 1 and 2, where the game-modes have a positive relationship with card entropy and deck entropy, with the exception of the Vintage game-mode on deck entropy. These models therefore lack support of hypothesis 3a. Model 12 shows a significant positive effect on technological ambidexterity. Model 15 does not show this significant effect. The game-modes have a significant positive relationship to technological ambidexterity. The data used for these models therefore do not support hypothesis 3b.

The lack of support for both hypotheses 3a and 3b can be attributed to the fact that the variance in the data is very low. Not many cards are banned every year and the amount of played cards which are currently banned is therefore also low. These minimal effects are greatly overshadowed by the changes to diversity and technological ambidexterity which occur due to game-mode differences. The variance of these variables per game-mode can be found in Appendix 6.

Conclusions

Competition is an important driver for innovation among many industries. Outside the business environment, competition is often seen as a necessary requirement for games and sports to remain fun and engaging. Magic: The gathering is a trading card game which requires competition, but moreover, competitive balance, for players to remain engaged and encourage them to return playing the game. Due to its high level of documentation since its inception, it was well suited to be used as a case study for innovations in such a competitive game environment. Wizards Of The Coast continuously needs to innovate within the game to maintain competitiveness with other similar games, but also to maintain its internal competitive balance. The type of innovations that are introduced and how they affect its competitive situation can prove to further mature innovation literature.

Three strategies of introducing innovations into the competitive environment were assessed in this research. The strategies used are defined by Saviotti & Metcalfe (1984) which are the following: (1) a change in mixture of technical characteristics, (2) a change in absolute values of technical characteristics and (3) a change in the pattern of mapping. Which led to the following research question:

What is the effect of the strategies that are implemented to preserve competitive balance over generations in Magic: The Gathering?

Where competitive balance is defined as a dynamic concept which is susceptible to change, and by understanding that competitive balance is built up by both diversity and technological ambidexterity.

The research consisted of three main parts. First, literature on innovation from a science and technology perspective, and innovation management is used to create a meaningful definition of diversity and expand the ambidexterity concept to technological ambidexterity to be able to translate these concepts to game specific measurements. Thereafter a variety of sources were used to obtain all the required data on cards and deck usage throughout the history of MTG. Lastly, creating regression models assessing each strategy defined.

Based on the results the research question can be answered. With regards to the first strategy mentioned, changes in mixture, the results show that this strategy has a positive effect on both diversity and technological ambidexterity. Meaning that this strategy has a positive influence on preserving competitive balance. Allowing for multiple game-modes (mixtures) has proven to be the most important factor for improving competitive balance of the game *overall*. This distinction is important to note since the change in mixture does not increase competitive balance within game-modes, but it increases the diversity and technological ambidexterity of the game across game-modes.

The second strategy, changes in absolute values, has no meaningful effect on the competitive balance, according to the results. The Vintage, Legacy and Modern game-mode all have the scenario in which the number of available cards increases every year. However, the diversity and technological ambidexterity do not increase over the years. The number of banned cards only has minor changes over the years and does not result in any significant changes to the competitive balance with the data used.

The third and final strategy, changes in pattern of mapping, also provide no significant effects on the competitive balance. The strategy is not often used, resulting in data with a very low variance between tournaments for each game-mode.

The answer to the research question indicates that only the changes in mixture have a significant positive effect on the competitive balance. Where the other two strategies do not have any significant effect. This shows that simply the introduction of these types of innovation does not automatically increase the competitive situation, but requires a more in-depth analysis to function as a tool to increase diversity and technological ambidexterity.

Discussion

6.1 Limitations

There are some methodological limitations in this research. First, the dataset used for the regression models was relatively small. The large list of decks used across all game-modes were condensed to one score for each tournament, reduced from the eight decks used per tournament. This led to a situation where the amount of observations for each game-mode were slim. Secondly, some of the variables used to measure the strategies had only very little variance in the observations. This means that significant effects of these strategies will very likely not be found, but also that these strategies are not often applied.

The strategies were chosen as a means to ensure external validity, providing results that are generalizable outside of MTG. The extreme influence of game-modes on the other two strategies has diminished this effect. While this effect may very well be present in other (video) games, it's likely not the case outside of this domain, reducing external validity.

There is also a general limitation in using only the card identities rather than their specific purposes, lacking a more in-depth approach to the game. This results in the scenario where each card is seen as an individual piece of technology, contributing the same value to diversity. However, in practice multiple cards over the years may provide the same effect, indicating overlap with other cards. These effects are not taken into consideration here, also having an effect on the internal validity of the research.

6.2 Theoretical implications

This research explored the use of innovation concepts to explain how competitive balance is established and improved within the context of a trading card game. By doing so, a first step has been established for analysing the complex system present in (video) games. This can open up new ideas and hopefully be a starting point for other scholars to also include this domain in innovation science research.

Secondly, the concept of ambidexterity has been extended to technological ambidexterity. Allowing for a situation where new and old components interact with each other. Where traditional ambidexterity literature often assumes that the new and the old do not interfere with each other directly, this is often not the case in (video) games. This extension is needed to indicate how well new and old technologies interact with each other. This concept can be applied to other domains where this interaction effect may occur and may provide new ways of approaching ambidexterity. This may be applied in transitions, for example in computer hardware and software, but also for transitions for example in renewable energy. Providing innovations which also are interacting and functioning well with previous generations can bridge the gap for consumers and allow for more easy transitions. This is therefore useful in scenario's where the old generations need to stay relevant, but also where the end goal is to only have the new generations active.

Furthermore, this research has provided a method for building the concept of competitive balance through diversity and technological ambidexterity. While competitive balance has a clear definition and is easily understood, it requires tools to be measured in the (video) game domain. Where in sports, the players often are required to use the same materials in competing, this is often not the case for (video) games. What constitutes competitive balance when players are allowed to use a wide variety of game elements is an important factor in understanding how this competitive balance changes over time.

Lastly, it has shown that the concept of diversity and the strategies for altering technical characteristics can be well translated to the (video) game domain. This further cements and accepts these theories within the innovation science domain.

6.3 Societal implications

The results of this research showed that the use of game-modes was the only significant contributor to improving competitive balance. This result can be of use for Wizards of The Coast specifically andother (video) game developers, but may also be of interest for innovation policy makers. The notion that adding more components to the game does not lead to an increase in competitive balance on its own is important to take into account. The data shows that the diversity for each of the game-modes does not increase with the current strategies in place, which creates a need to alter the existing or find new alternative strategies to see an increase in diversity if it's sub par. This problem also exists in innovation policy, where there is the challenge of either implementing technology specific or technology neutral innovation policy. The question whether adding more components actually leads to more diversity is very much a challenge in this domain and may take lessons from a dynamic environment such as (video) games.

Secondly, the technological ambidexterity had enormous variations between years, indicating there was no pattern with regards to these values. This could indicate that the years that technological ambidexterity was high could be attributed to luck. Keeping a close eye on older iterations when designing new ones is therefore an important step in trying to preserve this technological ambidexterity.

Finally, it is understandable there is a need for (video) game developers to sell new components they add to the game. However, when these new components replace the older ones, or if they are not able to combine well with older generations, they decrease the competitive balance. Developers would benefit from searching for a situation where these two practices of wanting to sell new components and optimizing competitive balance are practiced mutually.

6.4 Further research

With regards to MTG as a case, more in-depth research is likely to achieve more knowledge on how the competitive balance specific to MTG is preserved. This can be achieved by focusing on card level variables. Using methods such as natural language processing can be used to analyse text on cards to analyse diversity on the technical characteristic level. This may also be combined with card performance data, to find out which cards synergise well with other cards. These processes can lead up to more game specific knowledge which can help to understand and find ways to improve the competitive balance within MTG.

Furthermore, the world of (video) games is a highly under researched area with regards to analysing the games environment and its dynamics. They are most often only studied with regards to purely technical advances. As the market for games grows, and the level of competition within these games also grow, for example through professional esports leagues, their internal dynamics can be of great interest for many scientific fields. The science of patents and publications is another domain where the question of how to increase diversity and competition is important. It is widely known that purely applying for more patents does not necessarily increase the diversity of inventions or innovations. A search for strategies or policies that increases the diversity among innovation can therefore be of interest.

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Appendix 1

List of card variables.

Artist	Name of the artist that illustrated the card art.
asciiName	The ASCII (Basic/128) code formatted card name with no special unicode characters.
availability	List of the card's available printing types.
borderColor	Color of the card border.
colorIdentity	List of all the colors found in manaCost, colorIndicator and text.
colorIndicator	List of all the colors in the color indicator (The symbol prefixed to a card's types).
colors	List of all the colors in manaCost and colorIndicator. Some cards may not have a value, such as cards with "Devoid" in its text.
convertedManaCost	The converted mana cost of the card.
count	How many of this card exists in a relevant deck.
duelDeck	An indicator for which duel deck the card is in.
edhrecRank	Card rank on EDHRec.
faceConvertedManaCost	The converted mana cost of the face of either half or part of the card.
faceName	Name on the face of the card.
flavorName	Promotional card name printed above the true card name on special cards that has no game function.
flavorText	Italicized text found below the rules text that has no game function.
foreignData	See the Foreign Data data model.
frameEffects	The visual frame effect.
frameVersion	Version of the card frame style.
hand	Starting maximum hand size total modifier. A plus or minus character precedes an integer.
hasContentWarning	If the card is marked by Wizards of the Coast for having sensitive content. Cards with this property may have missing or degraded properties and values.

hasFoil	If the card can be found in foil.
hasAlternativeDeckLimit	If the card allows a value other than 4 copies in a deck
hasNonFoil	If the card can be found in non-foil
identifiers	See the Identifiers data model.
isAlternative	The card has some kind of alternative variation to its printed counterpart.
isFoil	If the card is in foil.
isFullArt	If the card has full artwork.
isOnlineOnly	If the card is only available in Magic: The Gathering Online.
isOversized	If the card is oversized
isPromo	If the card is promotional.
isReprint	If the card has been reprinted.
isReserved	If the card is on the Magic: The Gathering Reserved List.
isStarter	If this card is found in a booster pack.
isStorySpotlight	If the card has a story spotlight.
isTextless	If the card does not have a text box.
isTimeshifted	If this card is "timeshifted", a feature from Time Spiral block.
keywords	All keywords found on a card.
layout	Type of card layout.
leadershipSkills	See the Leadership Skills data model.
legalities	See the Legalities data model.
life	Starting life total modifier. A plus or minus character precedes an integer. Used only on Vanguard cards.
loyalty	Planeswalker loyalty value.
manaCost	Mana cost of the card.
name	Names of each face on the card. Cards with multiple faces, like "Split" and "Meld" cards are given a delimiter. Example: Face 1 Name // Face 2 Name.
number	Number of the card. Can be prefixed or suffixed with a * or other character for promo sets.

originalText	Text on the card as originally printed.
originalType	Type as originally printed. Includes any supertypes and subtypes.
otherFaceIds	List of UUID's of this card with counterparts, such as transformed or melded faces.
power	Power of the card.
printings	List of sets the card was printed in, in uppercase.
promoTypes	List of promotional types for a card.
purchaseUrls	See the Purchase Urls data model.
rarity	Card printing rarity.
rulings	See the Rulings data model.
setCode	The set code that the card is from.
side	Identifier of the card side. Used on cards with multiple faces.
subtypes	List of card subtypes found after em-dash.
supertypes	List of card supertypes found before em-dash.
text	Rules text of the card.
toughness	Toughness of the card.
type	Type of the card as visible, including any supertypes and subtypes.
types	List of all "card types" of the card, including Un-sets and gameplay variants.
uuid	A universal unique ID (v5) generated by MTGJSON. Each entry is unique.
variations	List of UUID's of this card with alternate printings in the same set. Excludes Un-sets.
watermark	Name of the watermark on the card.

Appendix 2

List of set variables.

baseSetSize	Number of cards in the set. Will default to totalSetSize if not available. Note that Wizards sometimes prints extra cards beyond the set size into promos or supplemental products.
code	Set code for the set.
isFoilOnly	If this set is only available in foil.
isOnlineOnly	If this set is available only online.
isPaperOnly	If this set is available only in paper.
name	Name of the set.
releaseDate	Release date in ISO 8601 format for the set.
totalSetSize	Total number of cards in the set, including promos and related supplemental products.
type	Expansion type of the set.

Appendix 3

The original deck format and the preferred deck format as a text file.

Original file
4 Koth of the Hammer
1 Chandra, Torch of Defiance
3 Pia and Kiran Nalaar
3 Stormbreath Dragon
2 Eternal Scourge
3 Anger of the Gods
4 Lightning Bolt
4 Skred
1 Magma Jet
1 Pyrite Spellbomb
4 Relic of Progenitus
4 Mind Stone
1 Batterskull
3 Blood Moon
20 Snow-Covered Mountain
2 Scrying Sheets

Preferred format
freq. name
4. Koth of the Hammer
1. Chandra, Torch of Defiance
3. Pia and Kiran Nalaar
3. Stormbreath Dragon
2. Eternal Scourge
3. Anger of the Gods
4. Lightning Bolt
4. Skred
1. Magma Jet
1. Pyrite Spellbomb
4. Relic of Progenitus
4. Mind Stone
1. Batterskull
3. Blood Moon
20. Snow-Covered Mountain
2. Scrying Sheets

Appendix 4

The results of a PCA analysis for the eight decks from 2006 for the Vintage game-mode.

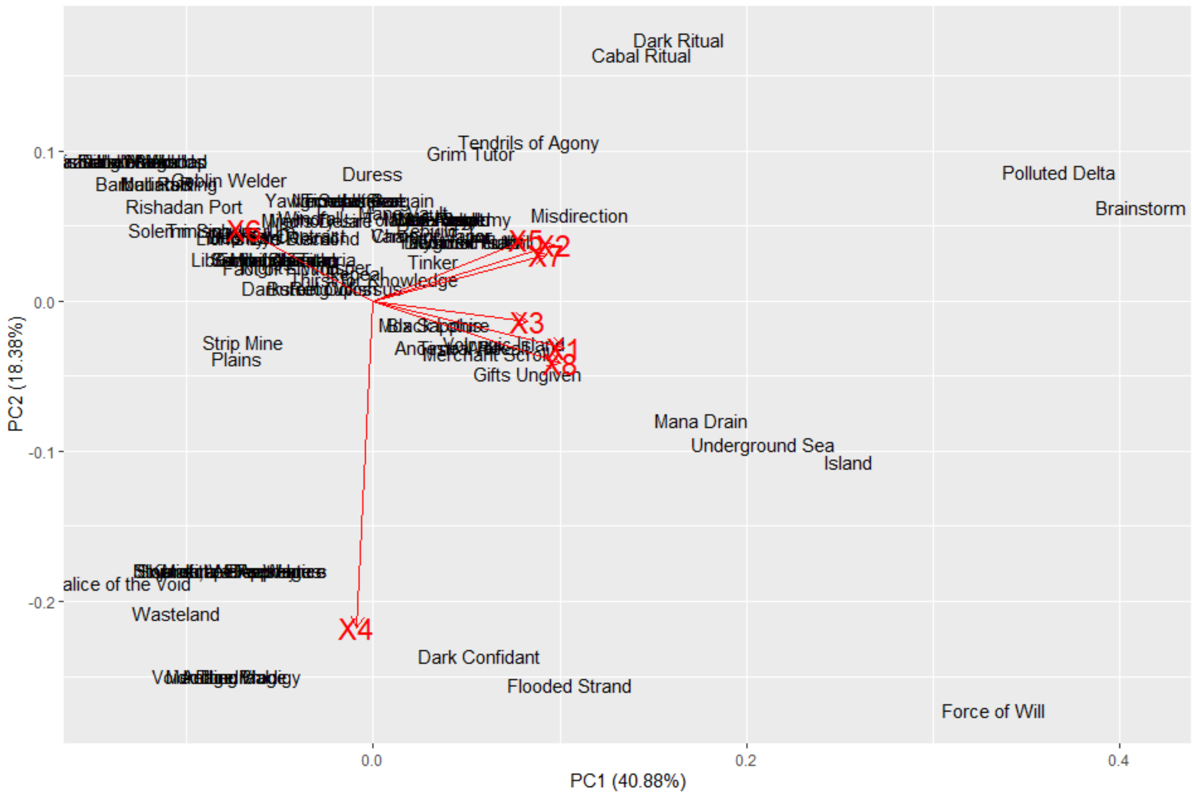
The factor loadings, using a cut-off of 0.4:

	PC1	PC2	PC3	PC4	PC5	PC6	PC7	PC8
X1	0.765	0.533						
X2	0.831	-0.456						
X3	0.660	0.448				0.445		
X4			0.853	0.452				
X5	0.641	-0.493			0.502			
X6	-0.416		-0.507	0.733				
X7	0.822	-0.415						
X8	0.801	0.472						

The explained variance:

	PC1	PC2	PC3	PC4	PC5	PC6	PC7	PC8
SS Loadings	3.615	1.398	1.049	0.821	0.587	0.401	0.081	0.046
Proportion var	0.452	0.175	0.131	0.103	0.073	0.050	0.010	0.006
Cumulative var	0.452	0.627	0.758	0.860	0.934	0.984	0.994	1.000

The plot showing the directionality of the decks:



It is clearly shown that decks 4 and 6 (X4, X6) are different from the other decks. Secondly there are two clusters of three decks (X1, X3, X8 and X2, X5, X7). This leads to a deck variety of 4. The names in the plot are the names of the individual cards used in the eight decks.

Appendix 5

The share of release years for the Vintage game-mode, 2005.

Cards for each release year

1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
162	29	7	33	30	4	28	3	31	83	41	31	2

Share of cards for each year

1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
33.4%	6.0%	1.4%	6.8%	6.2%	0.8%	5.8%	0.6%	6.6%	17.1%	8.5%	6.4%	0.4%

Perfect ambidexterity in this case would result in: 480 / 13 =~37 cards from each release year (7.69%).

Appendix 6

More detailed overview of independent variables for each game-mode

Standard **22 observations**	**Mean**	**Standard deviation**	**Minimum**	**Maximum**
Available cards	1474	254.41	973	1994
Banned cards	1.64	2.72	0	8
Unique banned cards played	0	0	0	0
Banned cards played	0	0	0	0
Cards banned in a year	1.64	2.72	0	8

Vintage **15 observations**	**Mean**	**Standard deviation**	**Minimum**	**Maximum**
Available cards	14050	3610.13	8870	20486
Banned cards	2.87	0.35	2	3
Unique banned cards played	0	0	0	0
Banned cards played	0	0	0	0
Cards banned in a year	0.07	0.26	0	1

Legacy **15 observations**	**Mean**	**Standard deviation**	**Minimum**	**Maximum**
Available cards	14050	3610.13	8870	20486
Banned cards	51.67	1.18	50	54
Unique banned cards played	1.93	1.10	0	4
Banned cards played	15.87	11.36	0	35
Cards banned in a year	1.067	1.03	0	3

Modern **8 observations**	**Mean**	**Standard deviation**	**Minimum**	**Maximum**
Available cards	10213	2162.95	7324	13556
Banned cards	33	1.51	31	35

Unique banned cards played	3.25	2.05	1	7
Banned cards played	20.38	11.84	4	44
Cards banned in a year	2	1.51	0	4

Appendix 7

A change in absolute values with acceptable variation inflation factors.

Results change in absolute values

	Dependent variable:					
	Card entropy	Deck entropy	Technological Ambidexterity	Card entropy	Deck entropy	Technological Ambidexterity
	Model 4	Model 5	Model 6	Model 16	Model 17	Model 18
Number Of Available Cards	0.577***	-0.381***	0.650***			
	(0.111)	(0.127)	(0.105)			
Number Of Banned Cards	0.076	0.522***	0.062			
	(0.077)	(0.088)	(0.073)			
Number Of Available Cards Transformed				0.161	-0.382	-1.020*
				(0.639)	(0.819)	(0.608)
Number Of Banned Cards Transformed				-0.117	0.049	-0.044
				(0.161)	(0.206)	(0.148)
GameModeLegacy				1.359***	1.041***	1.640***
				(0.201)	(0.257)	(0.192)
GameModeModern				2.118***	0.911***	1.773***
				(0.250)	(0.321)	(0.237)
GameModeVintage				1.429***	-0.577**	1.719***
				(0.201)	(0.257)	(0.192)
Constant	-5.161***	2.252**	-5.753***	-0.989***	-0.233	-1.076***
	(0.871)	(0.991)	(0.820)	(0.134)	(0.171)	(0.122)
Number of years	22	22	22	22	22	22
Variance (Year)	0.052	0.08	0.012	0.04	0.08	0
sd (Year)	0.227	0.282	0.111	0.201	0.243	0
R-squared	0.499	0.36	0.586	0.614	0.395	0.68
Observations	60	60	60	60	60	60
Log Likelihood	-67.524	-75.221	-62.626	-57.780	-70.956	-53.156
Akaike Inf. Crit.	145.049	160.442	135.253	131.560	157.913	122.312
Bayesian Inf. Crit.	155.520	170.914	145.725	148.315	174.667	139.067
Note:						*p**p***p<0.01

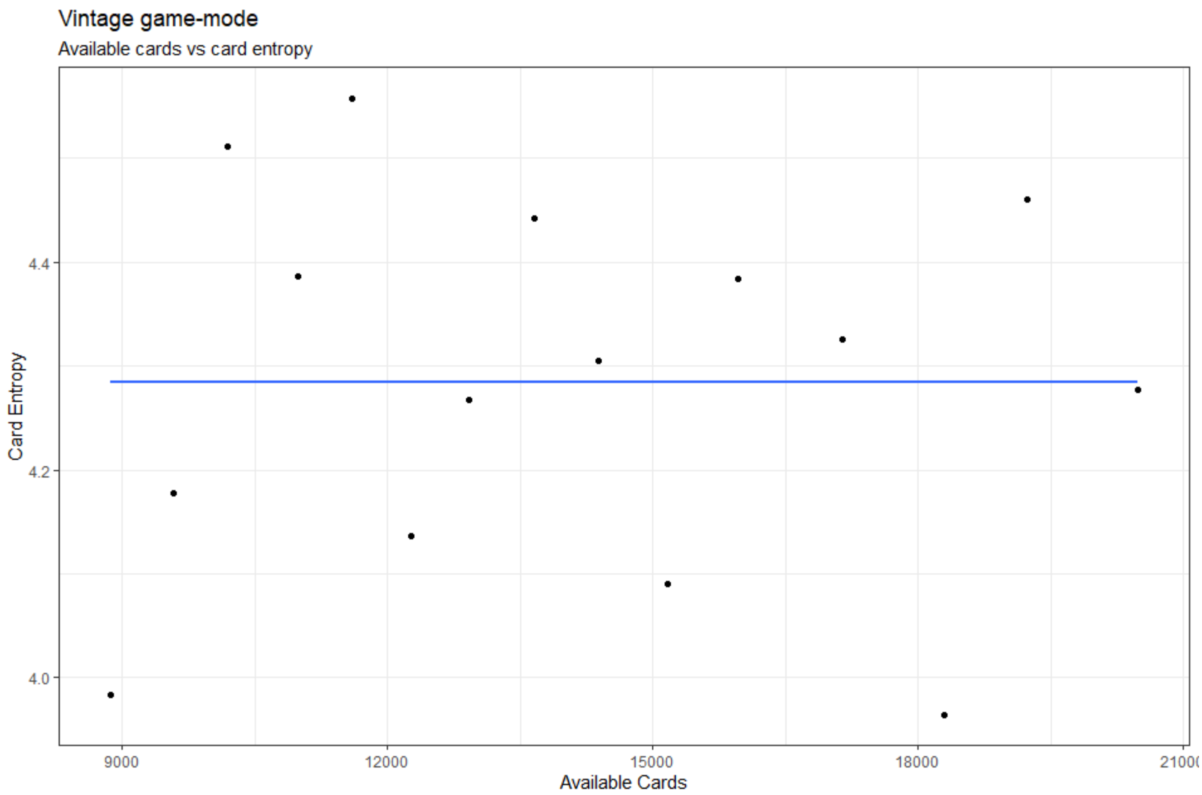
The models presented in section 4.1.2 showed an extremely high value for variation inflation factors (160.59). One way of bringing these variation inflation factors to an acceptable level is to work with residues of the independent variables that are uncorrelated to game-mode. These are created by making two models with game-mode as the independent variable and both number of available cards and number of banned cards as the dependent variables. The residues of these models are then used as the independent variables in Model 16, 17 and 18. This results in variation inflation scores of 1.00 and 1.01 which are acceptable.

The models presented here show that even with acceptable variation inflation factors, the effect of the number of available cards and the number of banned cards remain relatively the same as the model shown in section 4.1.2. This further cements the statement that hypotheses 2a, 2b, 2c and 2d are not supported by these results.

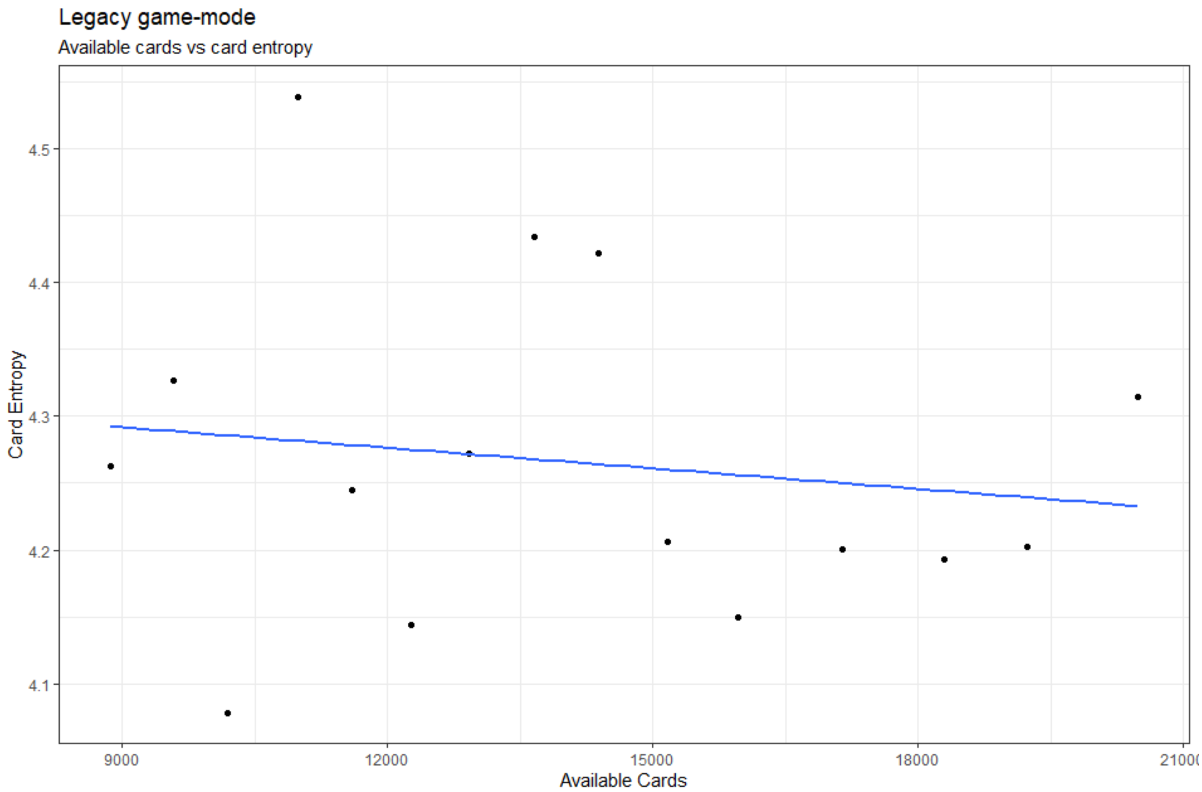
Appendix 8

Visualising the change in card entropy with the increase of available cards.

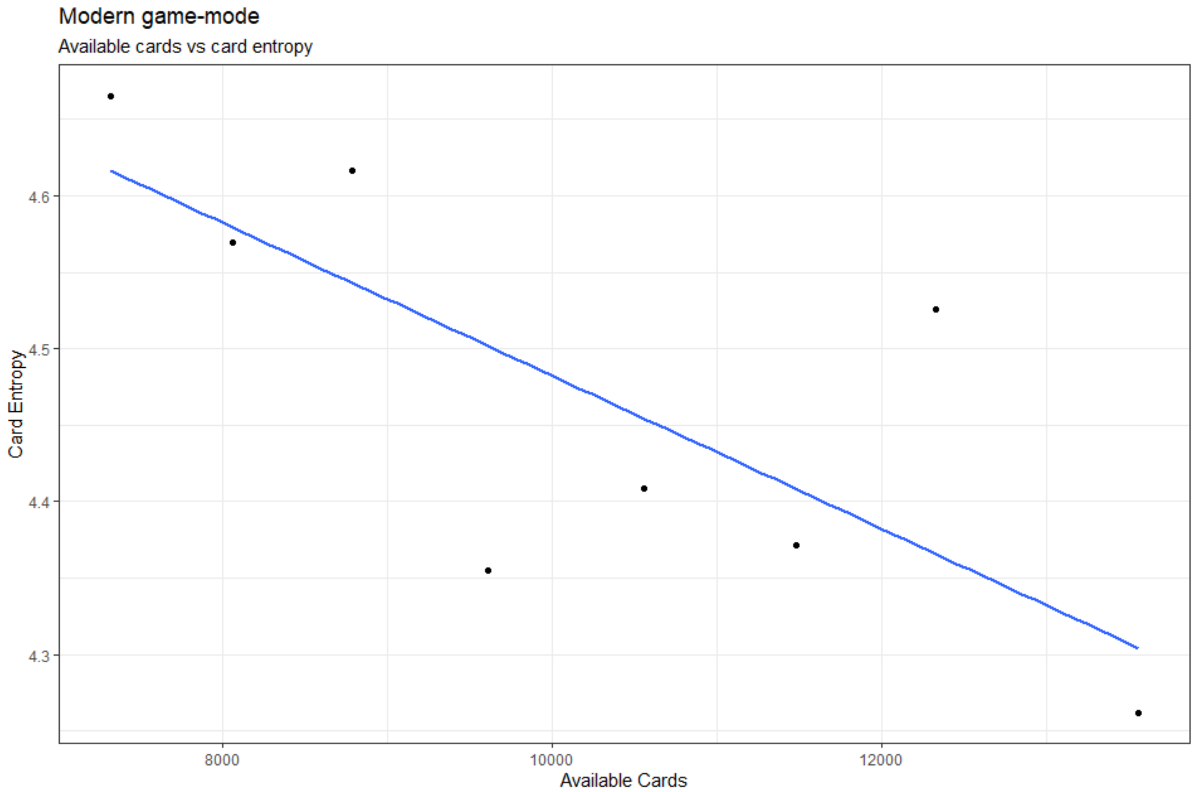
Vintage, Legacy and Modern are the three game-modes where each year, the number of available cards increases. This is opposed to the Standard game-mode, where the number of available cards is fairly similar each year. Visualising the number of available cards and the card entropy for Vintage, Legacy and Modern paints a picture which shows that an increase in available cards does not lead to an increase in entropy.



The Vintage game-mode shows that the observations are scattered in a manner where the trend line stays flat.



The Legacy game-mode shows a trend line that signifies a decreasing card entropy with the availability of more cards.



The Modern game-mode shows an even stronger decrease of card entropy with the number of available cards increasing.

A positive relationship between number of available cards and card entropy would result in a line that moves upward the further right it gets. These images clearly show that this is not the case within game-modes.