Economic Indicators for Decision-Making inOperating Massive Multiplayer Online Games

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Abstract*— Games are employing economic incentives, such as daily rewards, fidelity points, virtual goods and currencies, aiming to improve ARM funnel metrics related to Users Acquisition, Retention and Monetization. Massive Multiplayer Online Game (MMOG) go a step further creating virtual economies that increase the sense of ownership in players, improving retention [3]. Unfortunately, analyzing and managing virtual economies may be challenging, since there is a great amount and diversity of data to be considered. Economic indicators, largely used in the real economy, may be useful tools for analyzing MMOG economy, as well as conducting interventions. However, unveiling the economic indicators that are relevant ARM metrics is hard, since models for virtual economies presented in the literature do not address this issue. We identified only one research work proposing economic indicators for MMOG economies, but they are only two (inflation and nominal wages) and they have not been validated in any real-time game operation. In this paper, we propose six novel economic indicators for MMOG operators. We have preliminarily validated these indicators with experts; following we formalized the variables they depend on; then, we implemented a solution via a visual dashboard for a commercial MMOG. We collected the MMOG's data for the period of one year (six months before and six months after the use of the new indicators), covering 416,000 different players, with an average of 8,400 players per day. The results were amazingly positive. We obtained significant improvements in the main commercial metrics. Beyond its practical and solid results, we believe that another important contribution of our work is to draw the attention of developers into the interplay between economic science and games operation. We claim that the increasing introduction of economic elements in games should come together with the incorporation of concepts and tools for real world economics.

Keywords*— *Virtual economy, Massive Multiplayer Online Games, Economic indicators, Games analytics, Software as a service

I. INTRODUCTION

Games industry is one of the software-related industries in which the Software as a Service (SaaS) paradigm is better consolidated. For instance, all 100 top mobile games work on a SaaS business model called "freemium" [9], in which the mobile application is provided for free and the users must pay for additional features or virtual goods. This model requires the operation of several activities to support dynamic improvements and to drive the creation of new content.

In order to maximize user Acquisition (attracting new users), Retention (keeping users using the service) and Monetization (encouraging users to spend money on the service), the so called ARM funnel, games operators have been employing economic incentives - such as daily rewards, fidelity points, virtual goods and currencies - as a mechanism to improve user engagement and satisfaction. MMOG have been exploring this mechanism even further by creating virtual economies in which it is possible for users to trade virtual goods and services with each other, and to craft goods, creating value chains.

Despite the potential positive effect of economic elements in providing ownership in players and improving retention [3], these elements add a layer of complexity in the already challenging work of operating MMOGs. Indeed, MMOGs operation involves different problem categories. Beyond daily activities of any digital service, such as incident response, access control, service transition, and marketing, operators must pay attention to the virtual economy and its effects on competitiveness, balancing, enjoyability and immersion of players [22]. Indeed, problems such as inflation, wealth distribution and social mobility may impact the player experience [20].

Economic indicators, largely used in the real economy, may be useful tools for analyzing MMOG economy, as well as conducting interventions. However, unveiling the economic indicators that are really relevant ARM metrics is hard, since models for MMOG economies presented are generic, intending only to explain MMOG}economy, but not to provide practical information for supporting MMOG operators' daily decisions, who must sometimes act somehow like a central bank. To our knowledge, Tukka is the only work in the literature explicitly focused on economic indicators for games [32]. However, this work proposes only two macroeconomic indicators, inflation and nominal wages, and they have not been validated in any real-time game operation. In short, despite the importance of economics in games, we did not identify in the game literature solid foundations and

978-1-6654-3886-5/21/$31.00 ©2021 IEEE

enough tools aimed to support MMOG operators in daily decision making concerning economic issues.

We claim that the centuries-old knowledge of the real economy field can provide the means for also understanding virtual economic data and unveiling relevant indicators. In this light, our work proposes *6 novel economic indicators* to be used by MMMOG operators in their daily work. We have formalized, in an ontology format, the variables necessary to calculate them. Finally, we have developed a relational database with these variables and a visual dashboard to present the indicators and their underlying variables to game's operators.

In order to validate our solution, the indicator's dashboard was introduced in the operation of a commercial MMOG. We collected the MMOG's metrics for the period of one year, covering 416,000 different players with an average of 8,400 active players per day. We then compared the initial six months of game operation without the indicators (Dec/2018 to May/2019) to the following six months of operation with the adoption of the indicators (Jun/2019 to Nov/2019). The results of adopting the proposed economic indicators are quite impressive.

The following section brings an analysis of existing economic models for virtual economies. Section III presents the first original contribution of this work, the economic indicators for games virtual economy. The undergone validation and the obtained results are presented in section IV. Finally, we bring some conclusions and future works.

II. MMOG (Virtual) Economy

There is no doubt that the MMOG industry is part of the real world economy, since MMOG companies have employees, pay taxes, receive money from clients, have revenue and are susceptible to bankruptcy as any company. However, in this work, we do not focus on the real world economy, but rather on the virtual economy that permeates the virtual worlds of games: the MMOG virtual economy. The use of this terminology is supported by the semantic meaning of the term *economy*. According to the Oxford dictionary[1], *economy* is a system concerned with the wealth and resources of a country or region, especially in the terms of the production and consumption of goods and services. Thus, although virtual, there is a genuine economy controlling the MMOG worlds [4].

A. The nature of MMOG virtual economy

The economic aspect of games naturally arises from the fact that each player has aspirations that may never be fully satisfied with current virtual world resources. Managing resources under scarcity is the very basis of any economic system [20].

A regular game player needs virtual assets, including virtual goods and currencies in order to progress in the game [14]. For instance, players need (1) equipment to engage, protect or simply differentiate their avatars; (2) consumables to improve avatar performance and survivability in battles; (3) raw components to craft or improve equipment; and (4) currency to trade or pay for services such as equipment reparation, inventory extension, missions and virtual events access.

The player can gain access to these virtual assets by various means [14], like collecting materials (e.g minerals, herbs, and loots of any kind) in the virtual world; using materials to craft goods of his/her interest; being rewarded by performing actions and accomplishing quests; negotiating goods with other players, sometimes via auction houses; buying virtual goods from NPC and players using available currency (virtual or real); and so on.

Simpson proposes the "faucet-drain model" for describing virtual economic flow in Ultima Online[2], one of the first MMOG [25]. The faucet-drain metaphor suggests that virtual assets enter the economy through the action of players or operators out of nothing, like running water comes from the faucet, and these virtual assets may disappear without leaving residues, like water running down the drain. Unlike the real world, in virtual games the production and destruction of virtual goods are theoretically unlimited and does not leave residues. This way, the operator is responsible for calibrating the faucet and the drain in order to provide the scarcity feeling.

Wolf generalizes Simpson's model to be applicable to all MMOGs [34]. Wolf's model is composed of five components. In addition to Faucet and Drain, inherited from Simpsom's model, Wolf includes: *Circulation*, representing all kinds of trades and negotiations involving virtual assets; *Transformation*, representing the mechanics that turns virtual assets into others virtual assets; and what he calls "*Macroeconomy*" representing all mechanics with real currency, including In-app Purchases (IAP)[3] [13] and Real Money Trades (RMT)[4] [18].

Besides the fact that the economy influences various aspects of the game experience, improving the player's experience or not, the very economic activities of the player can directly contribute to the fun feeling [4]. For example, the sense of accomplishment is increased when the player finally buys a desired asset as a result of long efforts, or when the player receives a payment for complex work done. Creating and evolving a virtual asset as well as participating in bets and negotiations may also be a source of satisfaction and fun for the player.

B. Virtual economic indicators

Castronova, Simpsom and Wolf propose descriptive models to represent the MMOG economy [3,25,34]. However, there is a gap between economic models and decision making by policy makers and economic actors. To fill in this gap, economists make use of economic indicators, which are descriptive data used to analyse and forecast economy status [39]. For example, inflation and unemployment are indicators frequently used by central banks to establish interest rates, whereas Earnings Before Interest, Taxes, Depreciation and Amortization (EBITDA) is one of the main indicators to evaluate the financial health of a company. The models of Castronova, Simpsom and Wolf somehow help game

[1] https://www.oxfordlearnersdictionaries.com/
[2] https://uo.com/
[3] players buy virtual assets from the operator using real money
[4] players buy virtual assets from other players using real money

operators by structuring knowledge in a MMOG economy, but they do not explicitly propose economic indicators.

In fact, the literature is scarce on the explicit proposition of virtual economy's indicators that could help game operators on their daily decision making activities. An honorable exception is the work of Tukka [32], which, inspired by Castronova's work [4], has proposed and formalized two macroeconomic indicators for observing temporal changes in virtual economies: *inflation* and *aggregate production*. Inflation focuses on virtual assets prices to measure the average cost-of-living in virtual world and, consequently, user experience. Aggregate production, in turn, focuses on the average wealth generated in the world per player and how it affects the RMT. Tukka used these two indicators to analyze the economy of EVE Online[5], an online game operated by CCP Company with more than 200.000 users [32]. However, we point out that the effectiveness of using indicators has not been tested on real time game operation, in order to evaluate their impact on helping operators on their decision-making processes. The proposed operators have only been used to analyse, a posteriori, a database of the EVE online game corresponding to the activities that occurred in a past period of time (September 2005 to June 2007).

Given the complexity of MMOG operation, we believe that the use of only two economic indicators may be not enough for guiding operators' decision-making. Indeed, social mobility is directly influenced by microeconomic factors. For instance, whether a novice player can buy or not a given item from an advanced player has an impact on how fast this novice player can progress in the game.

III. A PROPOSAL FOR MMOG ECONOMICS INDICATORS

In this section, we present our six new economic indicators to help operators on managing the MMOG economy. They do not include Tukka's two indicators, which are oriented to macroeconomics. Our concerns are rather oriented to microeconomics, since it is the branch of economics that studies the behavior of economic agents (individuals and firms). That is exactly what we want to understand and influence: the economic behaviors of players.

Since the idea of introducing economic indicators to MMOG economy management is quite unexplored, a lot of possible indicators could be considered. Then, we decided to propose not too many indicators, in order to provide a more systematic evaluation of the impact of the adoption of them in the MMOG operator. Then, we biased our search for good indicators to those which provide information about the market (specially the trades among players). Indeed, both Castronova [3] and Simpson [25] have stated the more players are involved in commercial trades, the more fun the game tends to be. We also looked for indicators related to economic health of the game operation, since this is the most important concern of game operators.

A. Method

To reach the indicators, we proceeded in 3 steps. First, we analyse the literature, regarding real economics indicators as well as MMOG operation problems, to identify possible candidates to indicators. Second, we filtered them according to their relevance to the context of MMOG economy management. Third, we propose some adaptations of the remaining indicators to be applied in virtual context.

Analysing economics literature, two main macroeconomic indicators emerged: Consumer Price Index (CPI) and Gross Domestic Product (GDP) [16]. Diving into these indicators to understand how they are calculated, we arrived at some microeconomic indicators candidates, such as production rate and market scarcity. We also surveyed some papers discussing indicators for some specific sectors of real economy [31], yielding a few dozen more candidates for indicators (including macro and micro ones) such as: commodity production factor, basket definition, commodity price variation, government's investment, value of nation's total export and import. From the literature [40] concerning problems in operating Software as a Service, including games, we identified some more indicators, such as: Daily active users, revenue per user, cost per acquisition, trades volume and fair equality.

For the set of candidates, we have applied three exclusion criteria: *applicability*, verifying whether the indicator makes sense in a virtual economy; *scalability* to measure the capacity of the indicator to be generic enough to be applied in different virtual worlds; and *traceability*, referring to the possibility of logging the concerned data.

B. The economic indicators

We present here the indicators we propose. The first four indicators have a direct relation with game retention, whereas the last two are closely related to game monetization.

1) Item Quantity Variation - $IQV_{(i,d)}$

The economy manager (the MMOG operator, in our case) must monitor supply increase and try to minimize instability. Then, to help them, we proposed the indicator $IQV_{(i,d)}$ inspired by the Consumer Price Index [20], which includes item price in its calculation. As we discussed in section II-A, item is a subgroup of assets that includes virtual equipment, consumables and tradable assets.

$$stqQ_{30(i,d)} = \sqrt{\frac{\sum_{y=d-31}^{d-1} \left|Q_{(i,y)} - \mu Q_{30(i,d)}\right|^2}{30}} \quad (1)$$

where $\mu Q_{30(i,d)}$ represents the item average quantity and is given by:

$$\mu Q_{30(i,d)} = \frac{\sum_{y=d-31}^{d-1} Q_{(i,y)}}{30} \quad (2)$$

The $IQV_{(i,d)}$ is calculated as indicated in formula (3). It tries to capture the daily variation of the quantity with respect to the monthly variation.

$$IQV_{(i,d)} = \frac{Q_{(i,d)} - Q_{(i,d-1)}}{stdQ_{30(i,d)}} \quad (3)$$

The $IQV_{(i,d)}$ between -1 and 1 means a small variation of the supply. For instance, let us suppose that the availability of bricks is, on average, 70 units per day, varying from 65 to 75 in the last month. If there are 100 units available today, $IQV_{(i,d)}$ is equal to 6, which represents an abrupt increase of bricks availability. In this case, the operator should investigate the cause of such an increase which may be related to an exploit on game mechanics [19]; automatization of item farm [15]; unbalanced reward policies [27], or other causes.

2) Item Price Variation - $IPV_{(i,d)}$

[5] www.eveonline.com

For tracking prices, we proposed the indicator $IPV_{(i,d)}$, also inspired by the CPI. Given that $P_{(i,d)}$ represents the average price of an item (*i*) in a given day (*d*), the standard deviation of the price *P* of an item i is calculated for 30 days as shown in the formula (4), where μ is the average value of *P* of the time frame:

$$stqP_{30(i,d)} = \sqrt{\frac{\sum_{y=d-31}^{d-1}\left|P_{(i,y)}-\mu P_{30(i,d)}\right|^2}{30}} \quad (4)$$

where $\mu P_{30(i,d)}$ represents the average quantity and is given:

$$\mu P_{30(i,d)} = \frac{\sum_{y=d-31}^{d-1} P_{(i,y)}}{30} \quad (5)$$

The $IPV_{(i,d)}$ is calculated as indicated in formula (6). It tries to capture the daily variation of the price with respect to the monthly variation.

$$IPV_{(i,d)} = \frac{P_{(i,d)}-P_{(i,d-1)}}{stdP_{30(i,d)}} \quad (6)$$

To illustrate this formula, let us suppose that a brick has been negotiated by 10 virtual coins on average, varying from 8 to 12 in the last month. Today each brick is negotiated by 30 coins, $IPV_{(bricks,today)} = \frac{30-10}{2} = 10$, representing an abrupt increase in brick price.

In a MMOG, operators may explore the increase of an item's market price as an opportunity to introduce events (like limited offers or timed drops [28]) designed to improve retention or monetization. Whereas, the decrease of item's price can indicate that it is no longer desired by the players, representing an opportunity for operators to rebalance the game reduced offer of this item, and then regulating the market.

It is important to have both $IQV_{(i,d)}$ and $IPV_{(i,d)}$ indicators. They are related, but one cannot be inferred from another. Price depends not on supply only. In addition, a variation on supply cannot be easily noticed as price variation.

3) Trade Quantity - $TQ_{(d)}$

The more players interact with each other, the more fun is the game and the greater is player's retention [3]. One of the possible interactions among players involves asset negotiations [4]. To help operators in this task, we propose the adoption of the indicator $TQ_{(d)}$. Given $T_{(d)}$ as the set of trades performed by players in a given day d (formula 7), $TQ_{(d)}$ is calculated according to the formula (8) below, which is the cardinality of $T_{(d)}$ divided by the daily active users of the same day ($DAU_{(d)}$), representing roughly the quantity of trades per capita. This normalization is important to minimize the influence of users' evasion and acquisition in the indicator.

$$T_{(d)} = \{x|x\ is\ trade\ mane\ on\ a\ day\ d\} \quad (7)$$

$$TQ_{(d)} = \frac{|T_{(d)}|}{DAU_{(D)}} \quad (8)$$

To illustrate this formula, let us suppose that each active player of the game performs 2 trades per day on average. In the last week, the game registered 0.5 trades per active user per day, representing a decrease in player negotiations. In this case, the operator should act to heat the market and increase players' economic activity.

Indeed, $TQ_{(d)}$ can be used to set reward policies. If $TQ_{(d)}$ is low, the game operator can offer, as reward of an activity, some raw assets with currently high demand (using $IQV_{(i,d)}$ and $IPV_{(i,d)}$) in order to heat the market.

4) Quantity of Wealth Trade - $QWT_{(d)}$

Based on the economic concept of utility [6], we propose the adoption of the indicator $QWT_{(d)}$, representing the total amount of currency transacted during players negotiations on a given day d. $QWT_{(d)}$ is then complementary to $TQ_{(d)}$, capturing the total amount of transacted currency involved in trades. To calculate $QWT_{(d)}$, let us assume function $f_{(x)}$ (9) as being:

$f_{(x)} = T \rightarrow V$, where T is the set of trades and V is the set of traded values. (9)

Then $QWT_{(d)}$ can be represented as the summatory of values of all traded values on day d divided by $DAU_{(d)}$ to normalize $QWT_{(d)}$, according to formula:

$QWT_{(d)} = \frac{\sum_{t \in T_{(d)}} f_{(t)}}{DAU_{(D)}}$, where $T_{(d)}$ was defined on formula (7), and $DAU_{(D)}$ is the number of daily active users. (10)

An illustrative example to $QWT_{(d)}$ is. Let us suppose that each active player spends about 100 coins per day in trades. In the last week, each player spent about 50 coins per day, representing a decrease in currency transacted. In this case the operator must investigate the possible causes of decrease, which may be related to advanced players evasion, reduction on assets attraction or resource monopolization.

Clearly, capturing the utility of each trade is hard, since utility evaluation depends on various factors. For instance, buying a fire-resistance potion just before fighting a dragon is more useful than buying it for fighting a troll. Likewise, a trade between two players of the same wealth level is probably less useful than the same trade between a poor and a rich player, since in the latter case the trade may contribute to social mobility. Thus, $QWT_{(d)}$ is only an approximation of the trades utility. However, given that in Economics currency represents the perceived value of goods, we suppose that the greater are the values involved in a negotiation, the more relevant it is.

$QWT_{(d)}$ could be used by the game operator, for instance, to understand the necessity stimulating trades among players.

5) Active Payers - $AP_{(d)}$

Business operator plans considering trends, especially income trends. To help operators, we propose the adoption of the indicator $AP_{(d)}$, which is calculated as the cardinality of the intersection of the set of payers (formula 11) with the set of daily active users (formula 12). This represents the absolute number of active players in a given day d that have spent real money purchasing virtual assets directly from the operator at least one time in the game (formula 13).

$$P = \{x|x\ is\ a\ player\ who\ made\ at\ least\ a\ purchase\ ever\} \quad (11)$$

$$DAU_{(d)} = \{x|x\ is\ a\ player\ who\ played\ on\ day\ d\} \quad (12)$$

$$AP_{(d)} = |P \cap DAU_{(d)}| \quad (13)$$

To illustrate the relevance of this indicator, let us suppose that a game has a stable $DAU_{(d)}$ means that the number of new users is similar to the number of evasions. However, if the majority of players who evaded were paying users, this can configure a critical problem to the operation.

6) Income Distribution - ID

Income concentration may be a danger in business [17]. In the service sector, each user is potentially an income generator. Then, monitoring the income origin is vital to operation success [17]. A healthy operation should avoid too high concentration of revenue in a few players. When this is detected, operators must create attractive options to diversify the number of payers.

The indicator ID, calculated as follow. $P_{(p.m)}$ (formula 14) is a function that returns the total amount spent, by making purchases in real money, by a given player p in month m. $Sm_{(m)}$ (formula 15) is the set containing the total amount spent by each player in a month m. The function $fs_{(s,m)}$ (formula 16) simply arranges $Sm_{(m)}$ in descendent order, enabling the plot of the curve of figure 1.

$$P_{(p,m)}: amount\ of\ purchases\ made\ by\ player\ p\ on\ month\ m \quad (14)$$

$$SM_{(m)}: \{x | x = P_{(i,x)} for\ each\ player\ i\ during\ month\ m\} \quad (15)$$

$$fs_{(x,m)}: \bigcup_{i=1}^{|Sm_{(m)}|} fs_{(i,m)} = Sm_{(m)}\ \&\ fs_{(x,m)} \leq fs_{(x-1,m)} \quad (16)$$

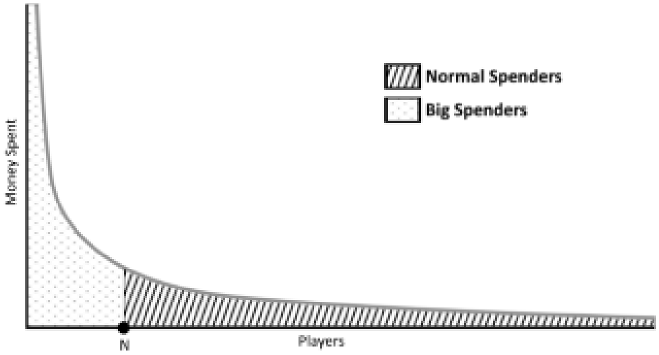

Fig. 1. Expected curve behaviour to $fs_{(x,m)}$, where $1 \leq x \leq |Sm_{(m)}|$.

From the curve of figure 1, we calculate the point N, representing the n^{th} player, which splits the total amount of money spent by users in a month into two equal areas, each one representing 50% of the total spent money by all players in month m. We call "big spenders" the players before N, and "normal spenders" those after N. N is calculated expanding and solving the equation of formula 17.

$$\int_{x=1}^{N} fs_{(x,m)} dx = \int_{x=N}^{|sm_{(m)}|} fs_{(x,m)} dx \quad (17)$$

Then, ID is finally calculated as the proportion of big spenders players with respect to all spenders as follows:

$$ID = \frac{N}{|Sm_{(m)}|} \quad (18)$$

The higher the indicator, the more secure the operation from the financial point of view. To improve this indicator, it is highly recommended to promote virtual assets with focus on stimulating "normal spenderes" to spend more and pushing non-spender players to start spending some money in the game.

C. *Solution formalization and implementation*

Each indicator presented in the last section needs a set of data to be calculated. For instance, to calculate IQV, we need to iterate over players' accounts to enumerate their assets. So, to use the indicators effectively, we need to capture, store and retrieve some game data. With that in mind, we developed an ontology to represent information, converted the ontology into a relational model and, finally, set up a dashboard.

According to each proposed indicator, different forms of visualization may be chosen. For instance Item Quantity Variation (IQV) and Item Price Variation (IPV) are presented as iterative tables (Figure 2). Some indicators, such as Quantity of Wealth Traded (QWT), Trade Quantity (TQ), Active Payers (AP) and Income distribution (ID), are shown in a timeline in order to favor the interpretation of trends (Figure 3). It is possible to interact with the timeline zooming a time frame and checking the value for each column.

Search:

Id	Qtd.	Std.	IQV
4054	97 (120.45%)	31.19	1.70
3356	7 (-12.50%)	3.44	0.29
3417	21 (10.53%)	8.69	0.23
2793	13 (-7.14%)	6.09	0.16
3188	58 (-4.92%)	25.97	0.12
2370	1935 (4.59%)	830.68	0.10
1731	454 (-3.81%)	202.67	0.09
2238	79 (3.95%)	34.55	0.09
2674	56 (3.70%)	24.18	0.08
3184	87 (-3.33%)	39.63	0.08

Previous 1 ... 600 Next

Fig. 2. Simplified visualization of the IQV indicator panel, hiding, for the sake of space, item name and historical histogram of item quantity

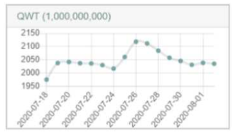

Fig. 3. Partial visualization of the QWT indicator panel, covering only some days

IV. Validating the Indicators in a Real Case

In this section, we present the results obtained by the adoption of the proposed economic indicators in a commercial MMOG named *With Your Destiny*.

A. *Evaluation Method*

We run an experiment in order to measure the impact of the adoption of the proposed indicators, visualized via a dashboard, in a commercial MMOG. We have chosen the MMOG With Your Destiny since we got full access to the game data as well as the agreement from the game's operators to modify their dashboard.

We decided to compare two periods of the game operation: 6 months before the introduction of the proposed economic indicators (dec/2018 to may/2019), and 6 months after the introduction of the indicators via dashboard (jun/2019 to nov/2019). For the sake of improving the paper comprehension, we call these two periods of *Before Indicators Introduction Period* (BIIP) and *After Indicators Introduction Period* (AIIP). During the whole observed period (BIIP + AIIP), *With Your Destiny* managed *416,000 different player accounts*, with *8,400 unique players per day* on average.

We have controlled the experiment avoiding to change any tools or indicators during one year. The only operation aspect that changed in the period, including frequency of game update and events, was the introduction of the indicators. It is also worth mentioning that the experiment occurred before the covid-19 pandemic, which has had a well known impact in the game industry [1].

Although the involvement of so many people for such a long time does reinforce the statistical solidity of the results, this may also raise threats to the validity of an evolving experiment. Indeed, there are a set of uncontrollable external factors like Community saturation [6], technical problems in the service [21], toxic community behavior [7], that could have occurred in the period, having a possible impact on the results. Moreover, the people that played during BIIP are not necessarily the same that played in AIIP, and even if they were the same, their behaviour can have changed by the simple fact that their relationship with the game and with the game community may have changed.

Considering the key performance metrics of the experiment, the ones selected were related to the ARM funnel and customer service, as detailed in the next sections.

B. Acquisition results and analysis

We observed an *increase of 22.3%* in the number of players during AIIP when compared to BIIP, indicating that the introduction of the indicators improved player acquisition. More precisely, during BIIP an average of 5,992 new players joined the game per month, whereas this number increased up to 7,330 during AIIP.

That said, we decided to be conservative and not consider acquisition augmentation as a result of the indicators adoption. In fact, the increase in player satisfaction, resulting from the improvement of the game, has only an indirect influence on the improvement of acquisition metrics, since satisfied players bring more friends to play [23],[26]. However, player acquisition may be sometimes more influenced by marketing campaigns than by game improvements [5]. That is why we are discarding acquisition improvement as a direct result of our work. We are reporting here acquisition changes only to weigh adequately the results concerning retention and monetization, since they may be influenced by the former. Put another way, we will use acquisition values to normalize the rest of the results in the ARM funnel.

C. Retention results and analysis

To measure changes in the retention rates in the two intervals (BIIP and AIIP), we used two classical metrics (Monthly Active Users (MAU) and Retention Matrix). We could have also used DAU, but since DAU corresponds to a shot period of observation (one day), it is unstable. MAU, which consider the entire month, is a more reliable metric.

1) MAU

In the BIIP, the game had 24,298 MAU on average, whereas in the AIIP, this number augmented to 30,030, representing an increase of 23.5% after the introduction of the indicators.

It's important to clarify that the increase on the acquisition, presented in subsection IV-A), influences positively the MAU value. However, we observed a higher increase on MAU when compared to players acquisition, as follows: players acquisition was (7,330 - 5,992) = 1,338 new players on average per month, while the increase in MAU was (30,030 - 24,298) = 5,732 more players engaged in the game per month. These values lead us to conclude that there was a real improvement in retention. In the worst case, even assuming that all newcomers remain active, which is never the case, we would have (5,732 - 1,338) = 4,394 of MAU increase, representing *18% of MAU augmentation* after the introduction of the indicators. In the analysed game the average of new players that become active is low as discussed in the next section.

2) Retention Matrix

Comparing the monthly average values of the retention metrics during AIIP with respect to BIIP, we observed the following improvements: d_7 improved by 28%; d_{14} improved by 28%; d_{21} improved by 31%; d_{30} improved by 37%; d_{60} improved by 60%; d_{90} improved by 90%. Comparing the final month of the AIIP with the final month of the BIIP, we also observe improvements: d_7 improved by 27%; d_{14} improved by 47%; d_{21} improved by 67%; d_{30} improved by 78%;d_{60} improved by 108%, d_{90} improved by 155%, which represent even better improvements (Figure 4).

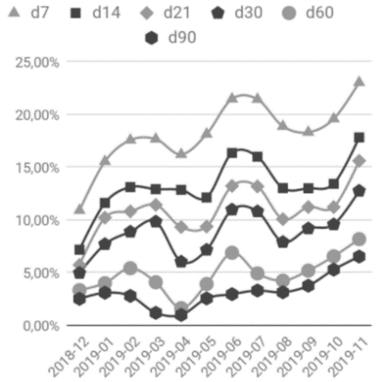

Fig. 4. Evolution of retention rate during BIIP and AIIP

The retention improvement in the long-term d_{60} and d_{90} can also be seen as a confirmation of the positive impact of the adoption of economic indicators. A player who stayed only a few days or weeks in the game has a lesser probability of being affected by the operators decisions based on the indicators. On the other hand, players who remain engaged in the game for a long time tend to be more affected by these decisions. In particular, given that older players often have accumulated more virtual goods, economic decisions tend to affect them more drastically. If they reacted positively to the decisions probably shows that these decisions were at least reasonable.

D. Monetization results and analysis

For measuring the impact of the economic indicators adoption on monetization of the game, we used the Conversion Rate (CR) and a variation of LTV. We also employed two other metrics, Time to Convert and Spent Variance, which will be presented later in this section.

The average value of CR MAU, which corresponds to the percentage of paying players among the active ones in a month, during BIIP was 1,46% (i.e., only 1.46% players spent some money in the game). It seems low, but this value puts our case on 4% better games in conversion according DeltaDNA[6]. During AIIP, CR went to 1.92%, representing a significant improvement of 31%.

CR focuses on how many people pay, but not on how much she or he pays. LTV can be used to capture the amount spent by each player during the entire period of use of the

[6] https://www.deltadna.net

service. As we focus our observation on only one year span, LTV may not be the best metric for capturing the money spent. Usually, the game industry uses Average Receipt Per User (ARPU) as an alternative measure for LTV. ARPU represents the money spent monthly per user on average. Comparing AIIP ARPU with respect to BIIP ARPU, we reached an improvement of 13.9%, which confirms that the adoption of the indicators yielded an improvement in game operators financial health.

As CR improved 31% and ARPU improved 13.9%, this means that we have a better distribution of the income. Instead of few players paying too much, we have more players paying less. This is a less risky situation for the operators, since their income becomes less dependent on few paying players, which may abandon the game, impacting the game finances a lot.

Another monetization metric we used is Time to Convert, which represents the time for each player to convert (i.e., to become a payer by making the first purchase in the game). We considered only the players who converted in less than 60 days. This metric is relevant because it helps the operator quickly detect the return over investment for each marketing campaign, making marketing operations more dynamic. During BIIP, the average time to the first conversion of players was 20.3 days. During AIIP, the average time to the first conversion of a player decreased to 8.9 days, representing a reduction in the time of conversion of 43.9% of the previous one, improving in 56.1% the conversion speed.

In short, with the introduction of the economic indicators in the game operation, we had more people spending money, people spending more money, a better distribution among payers of the money spent, and people converting earlier. In all aspects, the introduction of the indicators was a success.

It is important to note that the results of CR, ARPU, or time to convert metrics are relative values that disregard the increase in acquisition discussed in Section IV-A. However, there is a mutual influence between retention and monetization [2]. Retention positively affects monetization, since the longer the player stays in the game, the greater the chances of conversion, obviously. Still, monetization positively affects retention. In fact, when the player spends real money on a game, she or he tends to stay longer in the game. Note that the investment generally drives the user's progression in the game, in addition to increasing the player's sense of belonging [11].

V. Final Remarks

In this paper, we have discussed some challenges in analysing and managing MMOG virtual economic elements, which are part of the strategy of game operators to improve ARM funnel. We have shown that, unfortunately, the virtual economic models proposed in the literature do not provide enough information, such as economic indicators, to support the MMOG operators' daily decisions.

In this context, the main contribution of our work is to unveil six novel economic indicators for the MMOG virtual economy. We have formalized and then implemented them in a commercial MMOG via an indicators dashboard. We have observed the results for one whole year in this game that had 416,000 different players. The results we have are both statistically solid and impressive, since we have got improvements in the main ARM funnel's metrics after the introduction of the economic indicators dashboard.

More broadly, the second contribution of this paper is to draw attention of the game community to the potential of exploring the interplay between economics and the games operation. We claim that the increasing introduction of economic elements in games should come together with the incorporation of concepts and tools for real world economics. In this paper, we showed that the simple adoption of some economic indicators, inspired from real-world economics, yields excellent results in improving the ARM metrics.

To date, no need for change has been detected either in the ontology or in the relational model. However, we intend in a near future to include new economic indicators in the dashboard. First of all, we need to introduce other indicators to improve the interpretation and use of the ID indicator, by aggregating more detailed information on income concentration. We also are interested in a better tracking of social mobility in MMOGs in order to create the right incentives to avoid situations in which rich and poor players never negotiate with each other. This may include an inequality indicator similar to the gini index and other indicators that better qualifies market transactions [8]. Until now all indicators we suggested are focused on analysing the past. That is why, we intend to consider indicators that point to trends, helping operators anticipate market movements. Finally, we are looking for partners to test the adoption of the indicators dashboard in other commercial games.

VI. Acknowledgements

We would like to thank Raid Hut Games for providing access to data.

References

[1] Amin KP, Griffiths MD, Dsouza DD (2020) Online gaming during thecovid-19 pandemic in india: Strategies for worklife balance. Interna-tional Journal of Mental Health and Addiction pp 1–7

[2] Appel G, Libai B, Muller E, Shachar R (2020) On the monetiza-tion of mobile apps. International Journal of Research in Marketing37(1):93–107, DOI 10.1016/j.ijresmar.2019. 07.007

[3] Castronova E (2002) On virtual economies

[4] Castronova E (2008) Synthetic worlds: The business and culture of online games. University of Chicago press

[5] Choi D, Kim J (2004) Why People Continue to Play Online Games: In Search of Critical Design Factors to Increase Customer Loyalty to Online Contents. Cyber Psychology & Behavior

[6] Cristofari C, Guitton MJ (2014) Mapping virtual communities by their visual productions: The example of the second life steampunk community. Computers in Human Behavior 41:374–383

[7] Fahlstrom J, Matson E (2014) Preventing toxic behaviour through game ¨ mechanics

[8] Gini C (1912) Variabilita e mutabilit ` a

[9] Google (2020) Android Apps on Google Play

[10] Guerra B (2016) Quer diversificar a receita? O BI pode ajudar (e muito)!

[11] Heikkinen (2018) 5 New Ways to Use Monetization Features to Boost Retention. URL https://www.gamerefinery.com/ 5-new-monetizationfeatures-retention/

[12] Hioks P (2017) Differences Between Customer Support and Customer Service

[13] Hsiao KL, Chen CC (2016) What drives in-app purchase intention for mobile games? An examination of perceived values and loyalty. Electronic Commerce Research and Applications 16:18–29, DOI 10.1016/j.elerap.2016.01.001

[14] Knowles I, Castronova E, Ross T (2015) Virtual Economies: Origins and Issues. In: The International Encyclopedia of Digital Communication and Society, American Cancer Society, pp 1–6, DOI 10.1002/9781118767771. wbiedcs046

[15] Kosminsky E (2010) Virtual economies, virtual goods and service delivery in virtual worlds

[16] Kuepper J (2020) Top 5 Economic Indicators for Global Investors

[17] Lee E, Woo J, Kim H, Kim HK (2018) No silk road for online gamers! using social network analysis to unveil black markets in online games. In: Proceedings of the 2018 World Wide Web Conference, pp 1825–1834

[18] Lehdonvirta V (2005) Real-Money Trade of Virtual Assets: Ten Different User Perceptions. SSRN Scholarly Paper ID 1351772, Social Science Research Network, Rochester, NY

[19] Malerba C (2010) Vulnerabilidades e exploits: tecnicas, detecc¸ ´ ao e ˜ prevenc¸ao

[20] Mankiw NG (2001) Introducao a economia: principios de micro e macroeconomia. Campus, Rio de Janeiro, oCLC:50826545

[21] Paavilainen J, Korhonen H, Alha K, Stenros J, Koskinen E, Mayra F (2017) The pokemon go experience: A locationbased augmented ´ reality mobile game goes mainstream. In: Proceedings of the 2017 CHI conference on human factors in computing systems, pp 2493–2498

[22] Schell J (2008) The art of game design: a book of lenses. Elsevier/Morgan Kaufmann, Amsterdam ; Boston, oCLC: ocn213839335

[23] Schulze C, Scholer L, Skiera B (2014) Not all fun and games: Viral ¨ marketing for utilitarian products. Journal of Marketing 78(1):1–19

[24] Shalisman A (2014) The importance of uptime

[25] Simpson ZB (1999) The In-game Economics of Ultima Online. 1999

[26] Smit HT (2001) Acquisition strategies as option games. Journal of Applied Corporate Finance 14(2):79–89

[27] Smith B (2018) LTV or CPA: Which Matters Most When Scaling a Business? URL https://www. searchenginejournal.com/ltv-cpa/246547/

[28] Smith L (2015) Game Operations for All: Get the White Paper

[29] Sanchez JLG, Vela FLG, Simarro FM, Padilla-Zea N (2012) Playability: analysing user experience in video games. Behaviour & Information Technology

[30] Technavio (2018) Global MMO Games Market 2018- 2022

[31] Tjung LC, Kwon O, Tseng K, Bradley-Geist J (2010) Forecasting financial stocks using data mining. Global Economy and Finance Journal

[32] Tukka Lao (2008) Macroeconomic indicators in a virtual economy. PhD thesis, Helsingfors universitet

[33] Waddell J (2019) The Cascading Costs of Waterfall

[34] Wolf CA (2013) Case Histories and Analyses of Synthetic Economies: Implications for Experiments, Game Design, Monetization, and Revenue Maximization. PhD thesis, Kent State University

[35] Woo K, Kwon H, Kim Hc, Kim Ck, Kim HK (2011) What can free money tell us on the virtual black market? In: Proceedings of the ACM SIGCOMM 2011 conference, pp 392–393

[36] Yee N (2006) Motivations for Play in Online Games. CyberPsychology & Behavior

[37] Zagal J, Altizer R (2014) Examining 'RPG elements': Systems of character progression. In: FDG

[38] Zagal J, Bruckman A (2008) The game ontology project: Supporting learning while contributing authentically to game studies

[39] Zarnowitz V, Moore GH (1977) The recession and recovery of 1973-1976. In: Explorations in Economic Research, Volume 4, number 4, NBER, pp 1–87

[40] Hellemans, J., Willems, K., & Brengman, M. (2020). Daily active users of social network sites: facebook, twitter, and instagram-use compared to general social network site use. In Advances in Digital Marketing and eCommerce (pp. 194-202). Springer, Cham.