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Artwork by Anshe Chung Studios

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# Payback of Mining Activities Within Entropia Universe

By Markus Falk, Inova Q Inc., Daniel M. Besemann, Hamline University
and James M. Bosson, Active Capital Management Ltd.

## Abstract

*In subscription-based virtual worlds the fee a user pays for participation is clear. However, in free-to-play worlds in which the provider's revenue is generated via micropayments made by participants using a real in-world currency, lack of transparency in the underlying mechanisms can make it difficult for an user to gauge the service fee being paid. This paper studies the payback of mining activities within the virtual world Entropia Universe, with an aim to determine the cost of participation in this activity for users adopting a range of play styles. Entropia Universe provider MindArk estimates the normal service fee for an active user averages $1 per hour and we compare our findings to this figure. We employ a statistical approach, based on a large number of data points acquired by two Entropia Universe avatars, to develop a theoretical mining-returns model. This model was used to make predictions about general cost and profitability for Entropia Universe miners, resulting in an estimated payout percentage of at least 91%. Thus, over a sufficiently long period a miner can expect the provider to return at least 91 cents for every dollar invested. We also consider the effects of player-to-player transactions on a miner's real return rate. Our methods could be used to analyse the economy of other activities within Entropia Universe and possibly activities in other virtual worlds.*

**Keywords**: Entropia universe; virtual economy; participation cost; real cash economy; virtual world; MMOG.

# Payback of Mining Activities Within Entropia Universe

By Markus Falk, Inova Q Inc., Daniel M. Besemann, Hamline University
and James M. Bosson, Active Capital Management Ltd.

The cost of participation in a subscription-based virtual world (Bell 2008) is clear to the user. The fees the user pays to the provider are transparent and the user understands how much he or she pays for the service. In virtual worlds that do not rely on subscription fees to generate revenue, the cost of participation can be less transparent. This paper examines the cost of participation in one such virtual world—Entropia Universe.

Entropia Universe is a virtual world that attempts to combine the gaming focus of a traditional Massively Multi-player Online Role-Playing Game (MMORPG), such as World of Warcraft, with the social and commerce foci of virtual environments, such as Second Life. Developers MindArk describe it as a "3D Virtual Environment for Online Entertainment, Social Networking and E-commerce using a real cash economy" (MindArk, 2008a). Entropia Universe is set in the distant future on a planet called Calypso, the first planet successfully colonised by humanity. Participants control custom-built avatars and can explore two continents on the virtual planet, visit orbiting space stations, hunt alien creatures, mine for resources, and craft tools, weapons, armour, and clothes. Social interaction and trade are important and the top societies feature avatars worth tens, even hundreds, of thousands of US dollars. Avatars exchange items for prices that depend on the item's base-value (the price for which the developers will buy the item), use-value (how effective or useful it is), and exchange-value (how rare it is, and its aesthetic appeal or value as a status symbol), resulting in an in-world turnover of over $400M in 2007 (Mindark, 2008b).

Entropia Universe began development under its original name, Project Entropia, in 1995 and was commercially launched by Swedish developers MindArk PE AB in 2003 (MindArk, 2008c). It has over 800,000 inhabitants (MindArk, 2008d), although the majority of those are not active enough to have any impact on the economy. The virtual world is free to join and has no subscription fees. It features an in-world currency called the Project Entropia Dollar (PED) that is linked to the US dollar at a fixed exchange rate of 10 PED to $1, and revenue is generated by MindArk via participants making repeated micropayments (MindArk, 2008e) as they engage in the various activities available to them.

MindArk describes Entropia Universe as a virtual *universe*, rather than virtual world, and views the product as an expandable platform upon which third party developers can construct and maintain worlds of their own that exist within the same financial structure. A number of such worlds are in development at the time of writing and may not have the same gaming focus as Calypso, possibly developing more upon the social networking and e-commerce possibilities offered by the platform (Beck & Zaas, 2008; Choudhury & Behrmann, 2008; http://www.nextisland.com; www.rocktropia.com). For the purposes of this paper, we consider only Entropia Universe in its form at the time of writing, that is the MMORPG based around planet Calypso, developed and maintained by MindArk and its subsidiaries (MindArk 2009).

On Calypso participants engage in RPG-type gaming activities in which each action has a small but real monetary cost, in the hope of receiving loot they can sell back to the provider or trade with other participants. Revenue is generated by MindArk in the form of micropayments from these activities at a rate they estimate to be $1 per hour (or $0.5 to $1.5), for the average user (MindArk, 2008d; MindArk, 2009a). To go hunting alien creatures for instance, an inhabitant would need a weapon, ammunition, armour, and healing tools. All of these must be bought for PED either from MindArk at base-value (basic items, via in-world terminals) or from other participants at base-value plus a negotiable markup (more advanced items). Any item can be sold back to MindArk for its base-value at any point. Whenever an item is used, a small cost will be incurred and the base-value of the item will decay. Thus if a participant uses a weapon its base-value will reduce, and when a participant gets hit by a creature any armour protecting against the attack will lose value. Eventually items become unusable and must either be repaired (in exchange for PED) or replaced. When a participant kills a creature it may yield loot with a real monetary value that can be traded with other participants, possibly for more than its base-value. Whilst engaging in activities such as hunting creatures, the participant's avatar will also gain skills. These will enable the participant to perform actions more efficiently, and use higher level, more effective tools and weapons. Skills can also be traded with other participants in exchange for currency.

A key part of the economy is based on the supply and demand of items within Entropia Universe. Whilst all items have an assigned base-value, an item's actual value may be much greater if other participants are willing to pay the owner more for it. Item valuations are largely based on the achievement, social, and immersive player motivations described by Yee (2006) and applied by Manninen and Kujanpää (2007). In the Entropia Universe specifically, the value of an item depends upon factors such as how useful it is (a high damage weapon is likely to be more valuable than a low damage weapon), how efficient it is (a weapon that is cheaper to use is likely to be more valuable than an otherwise equivalent weapon), its availability, and its value as a status item. All are important in determining the valuation. In-demand clothes, which have exchange-value but no real use-value, will generally sell for less than in-demand tools and weapons that serve a purpose. For instance, the rarest and most appealing items of clothing trade for hundreds of USD whilst the rarest, most powerful weapons and tools regularly change hands for tens of thousands of USD.

When a participant engages in an activity there are generally three costs to consider–the system-generated decay of his equipment as he uses it, any markup he has paid to other participants for that equipment, and any tax he must pay on his finds. If the participant hunts or mines on land owned by another participant he will pay the owner a proportion of his finds. This results in a given percentage that is removed by the system from the base-value of any find and passed over to the landowner. He has three forms of return to consider–the base-value of his loot (the price for which he can sell it back to the system), any markup he could potentially make by selling it on to another participant, and the value of the skills he has gained through performing the activity. In terms of the service fee the user is paying to the provider, only the difference between the base-value expenditure and the base-value payout is important. All other returns or costs can be considered as trades with other participants. We study the system returns from one of the primary activities in Entropia Universe, mining for resources, with a view to determining how the result compares to the advertised average service fee of $1 per hour.

## Mining

Figure 1 is a visual representation of the mining process. In order to mine, a participant requires a tool called a *finder*, some mining *probes* or *bombs*, and another tool called an *extractor.* Additionally, it is possible to equip the finder with a mining *amplifier* that decays on its own and serves as a loot multiplier. There are two types of mining activities, enmatter and ore mining. For enmatter mining, a probe with a base-value of 0.5 PED is needed, whereas for ore mining a bomb with a base-value of 1 PED is used.


**Figure 1**: The mining process. A finder (eMINE OFS) is equipped and used with bombs (49 remaining) in the inventory (1). If a claim is found (2), a resource deed (3, 4) is placed in inventory. The finder points the avatar in the direction of the claim rod (5). An extractor is equipped and used on the claim rod (6). Each use of the extractor results in a stack of resources in inventory, until the claim is emptied (7).

At the chosen location, the finder is equipped and a probe (bomb) is released into the ground. The probe (bomb) searches within a certain radius before being expended and may or may not find a resource deposit. If a deposit is found, it must be extracted using the *extractor*.

The cost of the activity is the decay of the finder and extractor, the expenditure of the probe (bomb), and the decay of the amplifier (if used), with the vast majority of the cost residing in the probe (bomb) and amplifier. A single find consists of a deposit of one resource type expressed in units. Each different resource type has a base unit with a base-value (for instance, Gold is found as Gold stones, each stone having base-value 1 PED, and any number of stones can form a deposit). A deposit is found at a given depth (rarer resources tend to be found at lower depths) and has a given size.

Deposit sizes are very variable and can range from around 0.3 PED to tens, or extremely rarely even hundreds, of thousands of PED. A find worth over 50 PED results in a fanfare and an announcement in global chat. A find that is amongst the largest hundred of the day is also entered into a Hall of Fame. The resources found can be sold back to the provider or to other participants, or used to craft items which can then be cycled through the economy.

We perform a statistical analysis of mining returns and generate a view of the fee a miner pays the provider during the course of the mining activities. A model of returns is generated, consistent with our data sets, in order to simulate wide scale mining activity to get a view of how returns and fees look over the general mining community. Finally, we make some observations about how participants engaging in mining activities actually fare, after considering how markup on their finds could affect their results.

## Data and Methodology

### Data Collection

Two avatars collected data for this study and recorded a total of 4,911 finds out of 18,086 attempts (“drops”). They began data collection independently and became aware of each other’s work halfway through the acquisition process. Most data were collected between October 2008 and January 2009. Avatar A exclusively used probes on his mining runs, while Avatar B would used both bombs and probes. When a resource was found, both players recorded the resource type, the base-value of the claim in PED, amplifier used (if any), and the taxation applied (if any). These data were then compiled in spreadsheets for further analysis. Avatar A also recorded the finder and extractor used and the find rate (percentage of dropped bombs/probes that found a resource) for each run, along with other data not relevant to this work. Avatar B did not initially record finder or find rate data, but did begin collecting find rate data part-way through data collection. He then continued to collect find rate data after ceasing to record claim base-value, in order to provide a meaningful find rate comparison of the two avatars. Avatar B used a limited number of finders (with similar properties) and so an estimate of finder costs can be made. To estimate drilling costs a small dataset was provided by a third avatar (Avatar C) containing 152 drilling attempts using the least decaying extractor available on enmatter finds with a base-value of 0.01 PED.

### Loot Values

There are many ways to visualize individual loots. One such way is with the survival function. For a given loot value (x-axis), the survival function shows the probability (y-axis) that a loot larger than the given value will be obtained. The survivor function has a value of 1

(100%) for the smallest loot, and a value of 0 (0%) for the largest loot. To provide a non-parametric estimate for the survival function the Kaplan-Meier estimator (Kaplan & Meier, 1958) was used. In order to combine finds from enmatter and ore mining, taxed and untaxed finds, as well as amped and unamped finds, loot has been standardized accordingly. Figure 2 shows the survivor function for low base-value resources found without using an amplifier comparing enmatter and ore finds before and after standardization.

## Loot Classes

A number of conclusions can be drawn from Figure 2. First, loot is subdivided in classes. Each loot class has a fixed width, and there are gaps between loot classes. Second, the linearity of the survival function for each class means that the distribution within a loot class is uniform, i.e., there is an equal chance to loot between 0.50 PED and 0.80 PED of crude oil when loot comes from class 1. Third, the probability of receiving a class 1 find is between 0.4 and 0.5 for both enmatters and ores, since the survival function for class 1 extends from 1.0 to between 0.6 and 0.5 (i.e., 1.0 – 0.6 = 0.4). Analogous conclusions can be made for other classes. Fourth, the loot classes for ores are, within experimental uncertainty, twice the value of the enmatter classes. This doubling of the loot class value is due to the cost per drop: enmatter probes cost 0.5 PED, while ore bombs cost 1.0 PED. Similarly, the effect of a mining amplifier as well as taxation can be considered, so that observed loot can be standardized in order to have one combined dataset.

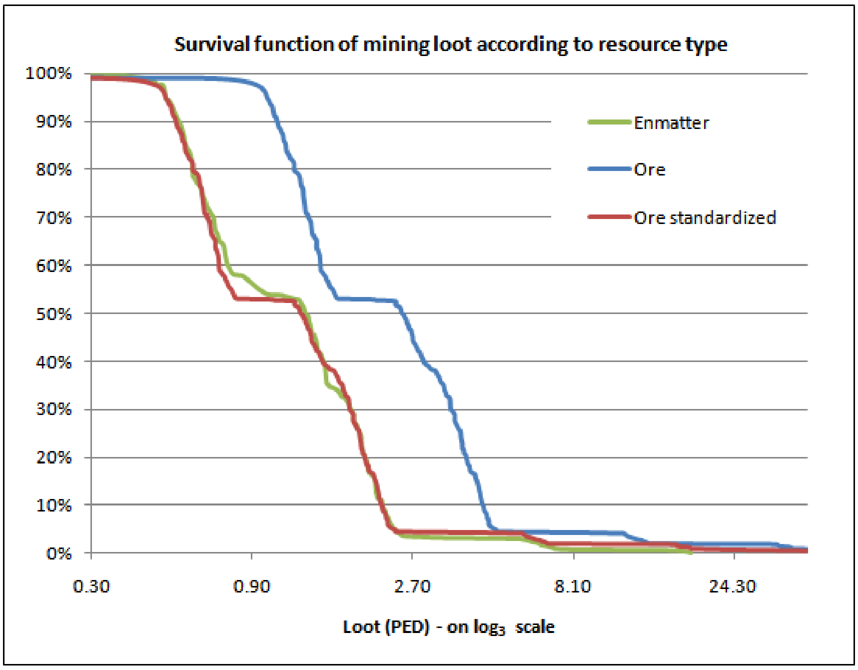


**Figure 2: Kaplan-Meier estimate of survival function for mining loot according to resource type before and after standardization**. Estimated survival functions on a $\log_3$ scale for untaxed and unamped enmatter loot in PED (n = 540, green line) as well as observed and standardized ore loot (n = 566, observed - blue line, standardized - red line). Enmatter loot is significantly different from ore loot before standardization ($p < .001$, Log-Rank test) but this difference disappears after standardization ($p = .943$ Log-Rank test). Similarly, it can be shown that the effect of taxation or the use of amplifiers disappears after standardization.

Consideration of all data confirms that loot classes do scale linearly with the cost per drop. Most data from Avatar A involved enmatter mining with a Matter Amp 104 (MA-104). The MA-104 decays 1.5 PED per drop, plus the 0.5 PED probe for a total nominal drop cost of 2 PED (nominal costs do not consider finder and extractor decay). Loot classes from Avatar A were observed to be four times larger than Avatar B's unamped probe data. Given this scaling effect, the data from any drop can be normalized by dividing by the number of 0.5 PED probe equivalents. Unamped ore bombs (costing 1.0 PED each) are therefore divided by 2, while a MA-104 probe drop is divided by 4.

### Statistical Analysis

Continuous data are expressed as mean and standard deviation, counted data as frequencies. For estimation of survival functions, we used the Kaplan-Meier estimator (Kaplan & Meier, 1958). Comparisons of survival functions have been carried out by means of the Logrank test (Mantel, 1966) and for differences in frequencies between groups the Chi-Square test was used. To estimate payout percentage, defined as percentage of returned money with respect to invested money, we derived a loot model for loot classes identified via the survival function. Expected loot consists of loot class means, estimated by means of linear regression on log-transformed loot values, and loot class weights according to the observed frequencies of loot classes. Mean cost per drop was estimated separately using a small set of recorded extraction data. If not otherwise possible, confidence intervals have been assessed by means of boot strapping. Using Monte Carlo methods we further assessed variability in payout percentage between different participants. A p-value less than .05 has been considered as significant and SPSS® 16.0, Matlab® 7.6 and Microsoft Excel® 2007 were used for statistical analysis.

## Results

### Payout Percentage

Avatar A has recorded a total of 1,998 amplified enmatter finds out of 7,360 dropped probes resulting in a find rate of 27.1%. After Avatar B began collecting find rate data, he dropped 1,380 bombs (373 finds) and 2,240 probes (611 finds), giving find rates of 27.0% and 27.3%, respectively, not statistically significantly different from each other ($p = .90$, Chi-Square test). Furthermore, the combined find rate of 27.2% for Avatar B is not significantly different from Avatar A ($p = .99$, Chi-Square test) and therefore overall observed find rate is estimated as 27.2% with a 95% confidence interval ranging from 26.3% to 28%. A summary of all finds used for analysis is given in Table 1 and the observed survival function is depicted in Figure 3.

**Table 1:** Finds according to mining activity, utilized amplifier, taxation and avatar.

| Mining activity | Amplified | Taxed | Avatar A | Avatar B | Total |
|---|---|---|---|---|---|
| Enmatter | no | no | | 540 | 540 |
| | | yes | | 175 | 175 |
| | yes | no | 1,622 | 429 | 2,051 |
| | | yes | 376 | 561 | 937 |
| Ore | no | no | | 566 | 566 |
| | | yes | | 252 | 252 |
| | yes | no | | 221 | 221 |
| | | yes | | 169 | 169 |
| **Total** | | | **1998** | **2913** | **4911** |

From the estimated survival function we have identified visually the respective loot classes and calculated mean loot value per loot class and loot class frequency. About 95% of finds are within or below loot class 2 and, in 5% of cases, loot will fall in one of the higher loot classes (Table 2). Loot is therefore heavily right-tailed. Furthermore, we do not have data for all loot classes yet. For instance, we have excluded one ore find with a base-value of over 12,000 PED, corresponding to a loot class 9 or class 10. Finds of this type are very rare and therefore we were not able to collect a reasonable number of finds for identification of respective classes. Loot classes one to six are however sufficient to estimate a minimal expected payout percentage. The given numbers are, however, subject to estimation error and therefore the sampling errors of loot class means, loot class frequencies, and find rate do need to be quantified in order to get a reliable estimate of the payout percentage.

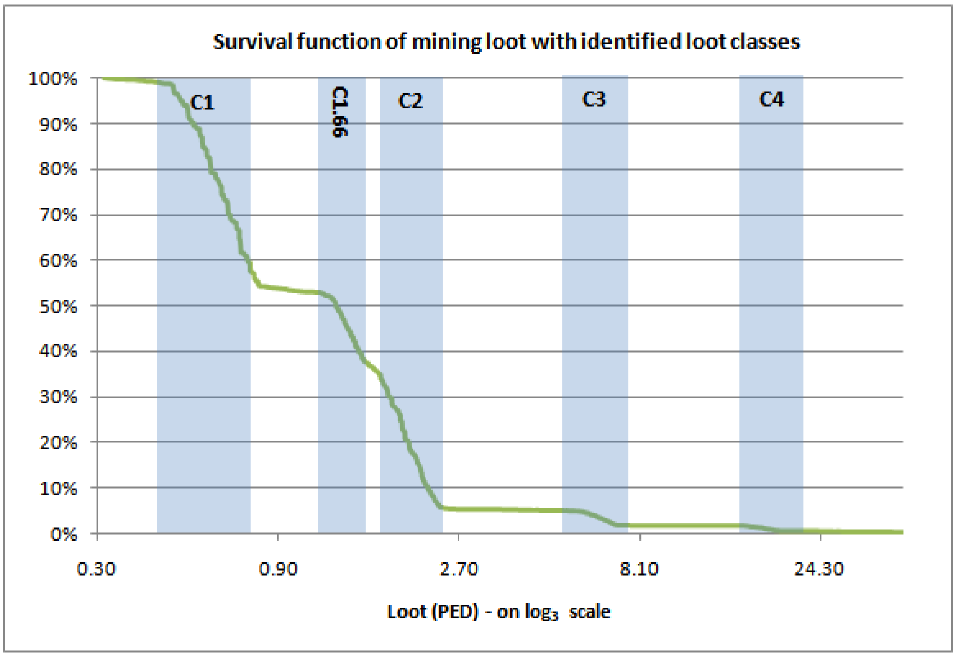


**Figure 3: Kaplan-Meier analysis for mining loot according to standardized loot.** The x-axis depicts the log-transformed standardized loot using the logarithm with base 3. For every value on the x-axis the y-axis gives the cumulative probability of a find in base loot above this respective value. Identified loot classes have been colored and numbered from C1 to C4.

Using linear regression, we were able to predict the log transformed loot class means from loot class numbers (see Figure 4), implying that the loot from one class to the next increases by a factor of three. From this we can conclude that loot classes are intentionally designed by the provider and that the loot class means from the regression shown in Figure 4 are the true ones and not further subjected to estimation error. Observed relative frequencies are, however, still estimates and therefore imprecise and have been adjusted accordingly (Table 2).

To calculate payout percentage it is necessary to know the sustained costs per find. Total cost per standardized find is composed by 0.5 PED for the probe plus 0.01 PED as finder decay (we use the lowest decaying finder here) and a variable amount of extraction costs depending on the number of found units. From the data provided by Avatar C, the mean extracted number of units per extractor use for resources with a base-value of 0.01 PED is 24 units ± 4 units (standard error of the mean 0.34 units). The decay of the lowest decaying extractor is 0.0033 PED. In Table 2 we summarize results for the estimated cumulative payout percentage.

**Table 2**: Identified loot classes for standardized loot with respective model means and frequencies (weights) as well as respective cost and cumulative payout percentage

| Class | n | Observed Mean (PED) | Observed Freq. (%) | Model Mean (PED) | Model Freq. (%) | Cumulative Mean Payout (PED) | Cumulative Mean Costs (PED) | Cumulative Payout Percentage (%) |
|---|---|---|---|---|---|---|---|---|
| **1** | 2295 | 0.64 | 46.74% | 0.66 | 47.00% | 0.084 | 0.513 | 16.3% |
| **1.66** | 677 | 1.35 | 13.79% | 1.36 | 14.00% | 0.135 | 0.514 | 26.3% |
| **2** | 1686 | 1.97 | 34.34% | 1.98 | 34.50% | 0.320 | 0.520 | 61.5% |
| **3** | 166 | 6.39 | 3.38% | 5.94 | 2.964% | 0.367 | 0.521 | 70.5% |
| **4** | 64 | 18.20 | 1.30% | 17.82 | 1.143% | 0.422 | 0.521 | 81.0% |
| **5** | 19 | 47.40 | 0.39% | 53.46 | 0.339% | 0.471 | 0.521 | 90.4% |
| **6** | 3 | 164.73 | 0.06% | 160.38 | 0.054% | 0.495 | 0.521 | 94.9% |

Model Mean is calculated using the formula given in Figure 4. Model Frequency gives adjusted observed weights in order to achieve a reliable lower limit for payout percentage; observed weights were rounded in the following manner: weights of loot classes 1 and 1.66 have been rounded upwards to the next percentage point and loot class 2 to the next half percentage point. This gives a cumulative relative frequency of 95.5% for classes 1 to 2, which corresponds to the respective upper limit of the 95% confidence interval for the combination of those three classes. The remaining classes have then been proportionally sized down, to give a total of 4.5%. Cumulative Mean Payout assumes an overall find rate of 27%. Cumulative Payout Percentage is calculated as Cumulative Mean Payout divided by Cumulative Mean Cost. Mean Cost was calculated as 0.51 PED (0.5 PED for probe and 0.01 PED of finder decay plus a variable amount of extractor decay depending on the loot class mean, leading to cumulative costs per find ranging from 0.513 to 0.521 PED.

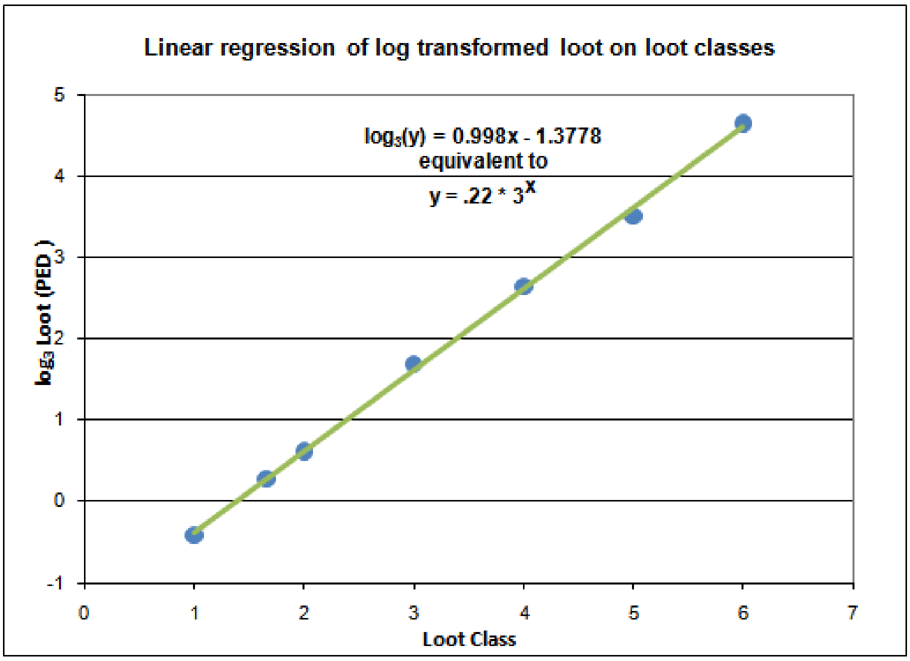


**Figure 4: Linear regression analysis of log transformed loot (y-axis) on loot classes (x-axis).** The linear relationship is clearly evident and therefore resolving the linear equation $\log_3(y) = x - 1.38$ for y, leads to $y = 0.22 * 3^x$. Hence observed loot for a specific class is based on a base loot value of 0.22 PED multiplied by the loot class number raised to the power of 3.

An avatar will usually see loot from loot classes 1 to 2 and get back about 60% of its investments, barring a below average find rate. In 4.5% of cases, loot will fall into one of the higher loot classes leading to a cumulative payout percentage of about 95% assuming a find rate of 27%. As find rate is subject to sampling error, overall payout percentage would be 91% or 98% using the lower (26%) or upper (28%) confidence limits of the estimated find rate, respectively.

The estimated payout percentage of 95% is expected to be observed over the long run. As loot from higher loot classes is rare, this could take many finds to achieve. We therefore simulated mining runs of different avatars using the loot model from Table 2 assuming an entirely random draw; the results are depicted in Figure 5.

Simulating 10,000 mining runs with 1,000 drops per run shows a highly variable payout percentage between avatars. About 30% of the runs will have a payout percentage equal or higher than 100%, thus managing a base-value profit. Only with a very large number of drops does the variance decrease and the expected payout percentage of about 95% is achieved by nearly every avatar. This also implies that different avatars might get a completely different impression about the loot system, when doing a low number of drops.

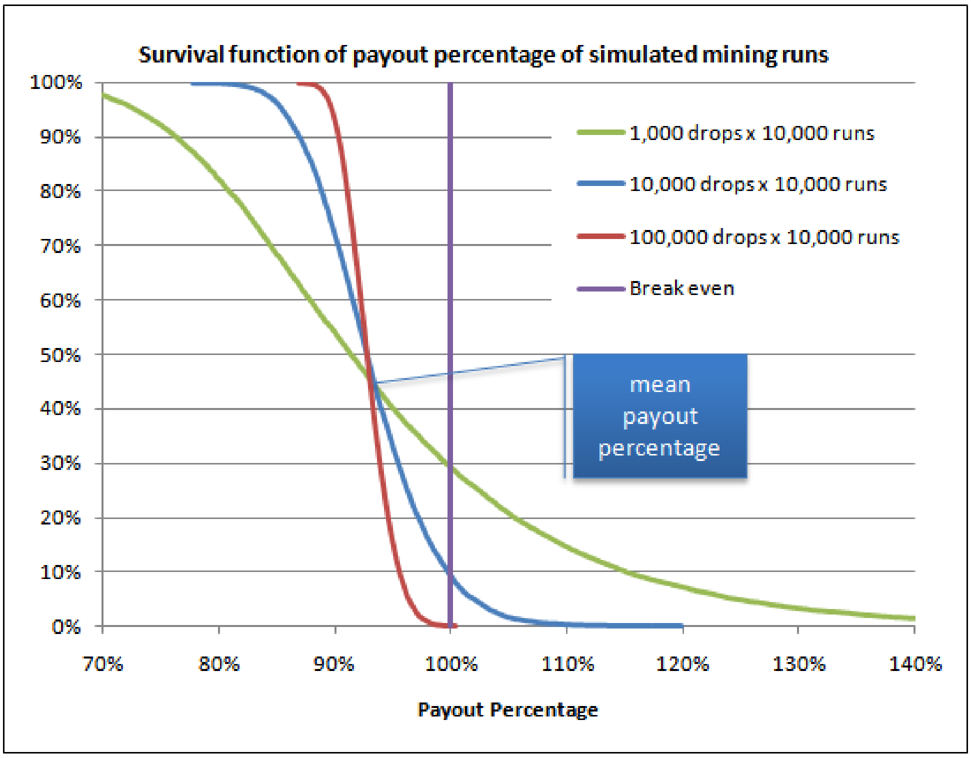


**Figure 5: Simulated mining runs with estimated survival function of payout percentage.** The x-axis depicts the cumulative payout percentage and the y-axis shows probability to observe a cumulative payout percentage greater or equal the given value on the x-axis. Using the loot model from Table 2 a given number of drops per run have been simulated. Thereafter, loot and cost have been summed up and the cumulative payout percentage per run has been calculated. The three different simulations all lead to the same mean payout percentage of 95% but their survival functions are clearly different, implying a higher variance with a lower number of drops.

## Cost Per Hour, Provider's Perspective

From the provider's perspective, the only costs that matter are base-value costs. Taxation and markup can be ignored, as these are merely transactions between players. Our estimated payout percentage of 95% implies that the provider (MindArk) retains, on average, 5% of the money spent on mining activities, thus returning to the player 95 cents (minimum 91 cents) for $1 played. From this perspective, the activity of mining is comparable to slot machines, where a spin costs a certain base-value and there is a long-term average payout (of 95%, in this case). This analogy breaks down when considering that found resources can be sold to other players with markup, discussed in the next section.

To compare to the stated $1/hour (10 PED/hour) cost to play, we must consider different play styles. Collating the experiences of many miners, a rate of 100 drops per hour is a reasonable estimate, though some avatars may drop more or less. The largest differences in play style come from the choice of enmatter (probes) and/or ore (bombs), as well as the size of amplifier used. Table 3 illustrates scenarios for different play styles, starting with the least expensive (unamped enmatter probing, nominal cost 0.5 PED per drop) and ending with the most expensive (ore bombing amplified with an OreAmp OA-109, nominally 21 PED per drop). It is clear that an average miner expending a nominal 2 PED per drop will provide the provider with its stated income by expending 208 PED/hour, with approximately 198 PED/hour returned to him in the form of resources, and the provider pocketing the remaining 10 PED/hour. Other miners with different play styles may lose as little as $0.26/hour or as much as $11/hour. Readers should note the rarity of high-end amplifiers and time spent extracting larger claims may impact the likelihood of achieving the latter extreme.

**Table 3**: Estimated base-value costs per hour.

| Nominal Cost/Drop (PED) | Example Setup | Gross Base-Value Outlay/Hour (PED) | Average Net Base -Value Loss/Hour (PED) |
|---|---|---|---|
| **0.5** | Probe, no amplifier | 52 | 2.6 |
| **1** | Bomb, no amplifier | 104 | 5.2 |
| **2** | Probe with MA-104 | 208 | 10.4 |
| **4** | Bomb with OA-104 | 416 | 20.8 |
| **8** | Probe with MA-108 | 832 | 41.6 |
| **21** | Bomb with OA-109 | 2184 | 109.2 |

Nominal cost/drop does not include finder and extractor decay, for simplicity. Gross base-value expenditure/hour assumes 100 drops per hour and 0.02 PED of finder and excavator decay per 0.5 PED nominal expenditure. Average net base-value loss/hour assumes a 95% base-value payout percentage.

## Cost Per Hour, Player's Perspective

While the provider is consistently collecting between 26 cents and $11 per hour from all miners (stated average of $1/hour), players are also competing against each other for funds that remain in the system (Lehdonvirta, 2005). The following discussion illustrates this zero-sum competition, which can result in some players withdrawing substantial funds from the Entropia Universe, while others continue to deposit into the system, having lost significantly more than the 5% removed by the provider.

From a miner's perspective, base-value is not the only cost that impacts his real return. Taxation and markup also play a significant role. As was mentioned, taxation and markup values amount to transactions between *players*. For a miner to break even or profit over the long term, the amount of markup gained from selling found resources must be greater than or equal to the sum of the base-value loss plus taxes and markup paid for the mining tools:

*Markup (resources) >= base-value loss + taxes + markup (finder, amplifier, excavator)*

Taxes are expressed as a percentage. Land area taxes are usually between 3% and 5% (we assume 4%) of base-value, meaning that of the 95% average payback, the miner receives approximately 91%, and the land owner (another player) receives 4%. Of course, there are many untaxed areas on Calypso that can be mined, but many land areas offer higher concentrations of rare resources and are mined regularly for these resources (and their high markup).

We define item markup as a percentage above base-value. Miners pay markup on some finders and extractors, as well as most amplifiers. We assume that repairable finders and extractors are used. These tools have no markup per-use, and thus our calculations are simplified. It should be noted, however, that some non-repairable finders have significant markup (over 100%, meaning the finder must be purchased from another player at twice the base-value) which can affect real returns, especially when mining unamped. The main source of mining markup is the amplifier, which currently varies from less than 5% for low-end amplifiers (101 amplifiers) to 50%-100% for the high-end amplifiers (107-109 amplifiers).

Markup on resources sold by miners is even more variable. The most common and least useful resources have markups of less than 5%, while the rarest useful resources command markups of 1000+%. Most of the latter are rare finds, even with the right equipment and knowledge, or have caps that limit the claim or class size that can be found, even with the use of large amplifiers. The markup on most resources is between 10% and 50%.

The skills gained while mining can also be sold for a markup to other avatars looking for a quick upgrade. As most avatars choose to keep their skills, we do not consider the market value of skill gains in this analysis.

Tables 4 and 5 show scenarios similar to those shown in Table 3, for various resource markups. Table 4 expresses real return as a percentage of real outlays, while Table 5 expresses real profit or loss as PED/hour. It is clear that play style has a more profound effect on real returns than it does on base-value returns. Those who enjoy playing “big” risk losing upwards of $100/hour while bombing with an OA-109 (with all but ~$11/hour going to other players), despite the appearance of good fortune (larger finds that are repeatedly announced in global chat). Others can break even (over the long run) or even make profits approaching those of a minimum wage job, if they choose the right equipment and use it to consistently find higher markup resources. Achievement of the returns in the 60% markup column are likely only achievable, if at all, by the most disciplined and knowledgeable miners, as the resources that can provide this type of return are uncommon finds and often cannot be found in large quantities. The 40% column is consistently approachable by knowledgeable miners, at least under favorable market conditions. It is important to restate that any profits, on average, are earned entirely from other players with different play styles and/or in-world professions (for example crafters).

**Table 4:** Estimated real returns as a function of mining setup and resource markup.

| Nominal Cost/Drop (PED) | Setup | Gross Real Outlay/Drop (PED) | Return (%) for Indicated Average Resource Markup (%) [taxed land] | | | |
|---|---|---|---|---|---|---|
| | | | 5% [9.8%] | 20% [25%] | 40% [46%] | 60% [67%] |
| **0.5, 1** | Probe or bomb, no amplifier | 0.52, 1.04 | 0% | 14% | 33% | 52% |
| **1** | Probe with MA-102 | 1.11 | -7% | 7% | 25% | 42% |
| **2** | Probe with MA-104 | 2.38 | -13% | 0% | 16% | 33% |
| **2** | Bomb with OA-102 | 2.26 | -8% | 5% | 22% | 40% |
| **4** | Bomb with OA-104 | 4.82 | -14% | -2% | 15% | 31% |
| **8** | Probe with MA-108 | 13.95 | -40% | -32% | -21% | -9% |
| **21** | Bomb with OA-109 | 36.84 | -41% | -32% | -21% | -10% |

Gross real outlay per drop assumes the same base cost as in Table 3, plus the following markups on amplifiers (as of 9/17/2009): MA-102, 14%; OA-102, 18%; MA-104, 20%; OA-104, 22%; MA-108, OA-109, 75%. Average base-value payout percentage is assumed to be 95%. Effects of a 4% land area tax are illustrated by replacing the listed resource markups with those in brackets (i.e. a higher resource markup is needed to achieve the same real return from a taxed land).

**Table 5:** Estimated profit (loss) per hour as a function of mining setup and resource markup.

| Nominal Cost/Drop (PED) | Setup | Gross Real Outlay/Hour (PED) | Average Net Profit (Loss) (PED/Hour) for Average Resource Markup (%) [taxed land] of: | | | |
|---|---|---|---|---|---|---|
| | | | 5% [9.8%] | 20% [25%] | 40% [46%] | 60% [67%] |
| **0.5, 1** | Probe or bomb, no amplifier | 52, 104 | 0, 0 | 7, 15 | 17, 34 | 27, 54 |
| **1** | Probe with MA-102 | 111 | (8) | 8 | 28 | 47 |
| **2** | Probe with MA-104 | 238 | (31) | 0 | 38 | 79 |
| **2** | Bomb with OA-102 | 226 | (18) | 11 | 50 | 90 |
| **4** | Bomb with OA-104 | 482 | (67) | (10) | 72 | 149 |
| **8** | Probe with MA-108 | 1395 | (558) | (446) | (293) | (126) |
| **21** | Bomb with OA-109 | 3684 | (1510) | (1179) | (774) | (368) |

Gross real expenditure per hour determined as in Table 4 and assuming 100 drops per hour. Average base-value payout percentage is assumed to be 95%. Effects of a 4% land area tax are illustrated by replacing the listed resource markups with those in brackets.

A comparison of Tables 4 and 5 reveals that the highest percentage returns do not necessarily provide the best per-hour returns. Further, as markups on both mining equipment and mined resources are constantly changing, real personal returns also vary, and the informed miner may need to change his play style. As an example, we might assume that mining equipment markup remains unchanged, while resource markup fluctuates. A miner who is able to consistently find resources averaging 40% markup might maximize profits by mining with bombs and an OA-104, achieving 72 PED/hour average real return. If the average resource markup suddenly drops, such that the miner can only average 20% markup on his finds, then this hypothetical miner is in trouble. He is well-advised to begin bombing with no amplifier, as his previous play style would now be costing him 8 PED/hour, while unamped mining might still yield a small profit. Risks such as these are found throughout the Entropia Universe, and interested players can and do spend a significant amount of time analyzing market values and adapting to changing conditions.

It is also true that if markup on all items dropped to 0% (meaning that items sold for base-value only), then miners and those in similar professions (hunting and crafting, assuming these professions have similar payout percentages) would all have, on average, a real return of approximately -5%, paid to the provider, with the real cost/hour depending on a player's expenditures/hour. This can be considered the entertainment value of the Entropia Universe experience.

## Discussion

### Limitations

The present study has several limitations that need to be taken into consideration. For instance, we have limited cost estimation to basic equipment. Other tools exist in-game with higher decay, offering faster extraction or enabling finds at greater depth. It is not well known if and how this additional decay is accounted for. Furthermore, we did not address rounding as loot is always converted to whole units of enmatter or ore. As rounding is only basically understood at this time, we have allowed fractions of units in our model, therefore only approximating the real observations. Moreover, although loot classes above 6 do exist our loot model truncates at class 6. However, as our main interest was to give a reasonable lower limit of the expected payout percentage and to show its basic characteristics, the mentioned limitations have only limited implications.

Throughout the document we have assumed that loot follows an entirely random process. Although we were able to identify a loot model, its implementation remains hidden. As we have seen from the simulation runs in Figure 5, payout percentage has a large variance and that there is even the possibility to achieve a base-value profit over the short term. On the contrary there is also the possibility for a payout percentage quite lower than 95%. As every random payout system tends to behave in this way, we leave open the possibility that the provider might have implemented a less random avatar-based correction mechanism, undetected by this study, that periodically adjusts an avatar's loot toward the 95% long-term payout percentage.

Finally, while no significant changes have been observed since these data were collected, it is true that the provider can modify the loot system at any moment without the need to inform participants, and therefore a constant monitoring of payout percentage might be necessary.

**Community Reactions**

The Entropia Universe community, in general, is a mature community that does not mind paying $1/hour for its entertainment. In fact, there is much positive reaction to the pay-to-play model, since time spent offline is free, in comparison to subscription-based formats. The community also appreciates the diverse array of activities available, going well beyond the main activities of mining, hunting, and crafting, some of which can generate revenue from other players, if pursued. There is a fair amount of negative feedback on the community forums, however. In general, the negative feedback with regard to cost to play takes one of two forms.

First, there comes a point at which it is nearly impossible to advance in a particular profession without expending significantly more than 200 PED base-value per hour (thereby generating more than 10 PED/hour in income for the provider). When players reach this point, they are left with a choice: either continue playing at their current level and risk monotony, or invest more money into the system in order to escalate the level of challenge experienced. It is at this point that the cost to play can become significantly higher than that of most subscription-based games for a similar level of challenge, and players become frustrated at their inability to advance at a reasonable cost.

Second, as has been shown, the loot distribution for mining (and indeed, hunting and crafting) is heavily right-tailed, with 4-5% of finds accounting for 35% of the payout. This distribution leads to some interesting threads and conversations on the community forums. When a player receives a large loot, such as the 12,000 PED loot mentioned earlier (or for some players, a class 5 or 6 loot), he or she often posts a screenshot on the forum. Most forum users congratulate the player on their good fortune. Others, often in response to particularly large loots received by lesser known (or sometimes, well-known) players, flame the lucky player's thread or start their own threads lamenting the injustices of the loot system. They present as “proof” their supposed miserable payout percentage and/or insane losses over some period of time.

Based on our data, we can only assume one of three things: these players have a very uneconomical play style (see Tables 4 and 5); they overemphasize bad luck periods and under-emphasize the good; or they have simply not cycled enough PED to have adequately sampled the entire loot distribution. As is shown in Figure 5, there is about a 20% chance that after 1,000 drops an avatar will have received less than 80% base-value payout. This corresponds to between 520 and 21,000 base-value PED expended, depending on play style. Registering complaints before cycling enough PED is not statistically warranted, but when real money is involved, it is easy to ignore statistical realities.

Whatever the reality, many players claim to have left the Entropia Universe because of actual or perceived losses. Many who stay feel that the universe would be a more enjoyable place if the loot distribution had less right-tail character, while others enjoy the occasional thrill of winning tens, hundreds, or thousands of dollars in a single loot, at the expense of enduring losses on most days. Further, some express the opinion that a more consistent return would reduce the number of negative reviews in cyberspace, ultimately increasing the Entropia Universe population, and with the hope that an increased population would allow the provider to increase payout percentages while maintaining profitability. Whether this viewpoint has merit is hard to say. The only thing that really matters is that, for the moment, the developers seem happy with the loot distribution and payout system.

## Conclusion

We have collected and analyzed thousands of individual mining loots in the Entropia Universe. Using these data, a model of the loot distribution system was developed and used to predict the payout percentage and average cost to play. It was determined that the loot distribution consists of discrete classes and is heavily right-tailed. A base-value payout percentage of 91%-98% was found to be consistent with the data, and that a miner expending approximately 200 PED per hour would have a base cost to play of approximately 10 PED ($1) per hour, consistent with the provider's claims of the average cost to play. Avatars expending considerably more or less than this amount would be paying the provider proportionally more or less.

We also considered the effects of play style, taxation, and player-to-player markup on returns. A player's individual play style heavily influences the personal return, with certain play styles costing significantly more than the average cost to play, and others generating profits from fellow players that exceed base-value play costs.

## Competing interests

The authors declare that they have no competing interests.

## Authors' contributions

Markus Falk, Daniel Besemann and James Bosson drafted the manuscript, Markus Falk also performed statistical analysis, and Daniel Besemann performed calculation of estimated real returns. All authors read and approved the final manuscript.

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