Creation of system examples for in-game economies utilizing the tool *Machinations*[1]

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[1] (Dormans, n.d.)

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Declaration of authorship

I hereby declare that I am the sole author of this bachelor thesis and that I have not used any sources other than those listed in the bibliography and identified as references. I further declare that I have not submitted this thesis at any other institution in order to obtain a degree. I have clearly indicated the presence of all materials from other sources. This includes texts, presentations, graphics, diagrams, still or moving images, code and sounds.

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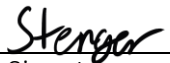
Germany | 11.02.2019 | Stenger Philipp | 

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Abstract

For this work, a summary of how real-world economic systems function on a basic level and how this translates to economic systems in video games has been created.

This work explains what the tool *Machinations* [2] is and what advantages it brings to development teams.

Additionally, a selection of prototypes that showcase, how the economic systems of video games can be altered in a way that allows to take more control of the level of inflation in video games, have been produced. These prototypes have been documented and evaluated to allow for a precise understanding of how their approaches function, how they can be utilized and what they can be used for.

This work also delivers an explanation of how the created systems can be extended to other types of games or how someone can start to create a new system.

[2] (Dormans, n.d.)

1. Introduction

Today's virtual economic systems have come a long way, featuring a large number of different approaches of how players consume, trade and produce for, with and in the in-game economic systems of games, while also delivering a large variety of different systems for different economies. But there are still a lot of problems. These problems become usually more apparent the longer a player interacts with the game. Many of these problems are 'fixed' by utilizing workarounds and not by actually adjusting the system to remove the error.

This work aims to create examples that explain how economies function within games and wants to break economies down to a basic construct from which this work will expend into different examples of virtual economic systems. This is done by utilizing the tool *Machinations*[3], which will be used to explain visually how these systems work on a basic level and will further be used to showcase how designers can build upon these systems to create their own economies utilizing this tool, identify problems in their current creation and modify them to test different approaches of how these problems could be solved. This work will also showcase how these tests can be evaluated.

In addition to that will this work aim to showcase how economic systems are structured in the real-world and how this compares to the virtual economies found in games.

This work is focused towards Game/System Designers that work on economic systems and Producers that manage the creation of these systems and aims to allow for a general understanding of how these systems could be approached. In addition to that, is this work also directed at any other member of a development team, to offer a general understanding of in-game economies and the problems that should be expected during their creation.

[3] (Dormans, n.d.)

2. The economy of our society

This chapter will focus on the economic systems of our society and therefore the economy of the real world.

This chapter will offer a general understanding about how entities interact with each other in an economic environment and will later be used to compare real-world economic systems to the economic systems of games. This chapter will also be used during the next chapters to point out what different approaches a virtual economy offers and what problems are created by current in-game economies.

2.1. Objects of basic economics

2.1.1. Goods and services

Economic entities focus on the creation and/or consumption of products. These products are described as goods and services. Goods are considered all of these products that can be defined as a physical object, while services are defined as tasks that are completed for other economic entities without the necessity to exchange physical objects. An example of this would be transportation.

2.1.2. Economic entities

Economic entities are entities that heavily effect and are affected by the economy. Examples for this are: Firms, individuals, governments, banking systems and insurance companies.

It should also be noted that an economic entity is explained in the way a legal entity functions while a legal entity itself simply proves that it exists.[4]

2.1.3. The economic system:

The economic system is a large set of inter-related production and consumption activities based on which economic entities decide how resources should be allocated.[5]

2.2. The definition of economies

"Economy defines itself as an entire network of producers, distributors and consumers of goods and services in a local, regional or national community."[6]

[4] (Andrei, 2013, p. 240)
[5] (Andrei, 2013, p. 13)
[6] (Business Dictionary, Definition Economy, n.d.)

Based on this it can be said that an economy is a set of related production and consumption activities based on which economic entities decide how resources should be allocated. This is also known as an economic system.[7]

This means, that an economy defines all activity related to production, consumption, and trade of goods and services in an area. An economy applies to everyone from individuals to entities such as corporations and governments. The economy of a certain area or country changes based on its culture, laws, history, geography and other factors. It adapts out of necessity. Due to this development, it can be determined that most if not all economic systems differ from each other.[7] In economies producers and distributors exchange goods and services with consumers. In addition to that economies can be divided into sub-areas based on location or related services. These areas do also exist within the view of all economic systems and can be viewed independently and in relation to the other market participants. It is important to note that all economic systems interact with each other, unless they are completely divided by location, politic, religion or another force that is able to isolate all forms of interaction between whole economic systems.

2.3. Micro- & Macro-economics

The overall difference between micro- and macro-economics is that micro-economics focus on individual economic entities, while macro-economics study an economic system of national or federal economic scale, a large system formed by a number of different micro-economic entities.[8]

Considering this structure and the relation between micro- and macro-economics it becomes possible to understand the effects that micro-economics have on a macro-economic level. These pieces of information can be utilized to develop an understanding of what aspects or events in a society result in which economic development and therefore allow to evaluate if these events, political changes, ethical changes or other influencing factors have a positive or negative effect on the desired market situation.

This also works in reverse, by evaluating the changes within the development of an economy. This can be done by studying the effect that micro- & macro-economics have on politic, ethic, income or other influencing factors. This makes it possible to determine, what can be considered positive or negative depending on whatever the authority behind an economic systems considers desirable.

2.4. Goals of economies

The goal of most economies is the creation of a system that allows different economic entities to interact with each other in a profitable way, to supply all consumers with the goods and services they need or want and in extension to increase economic growth.

[7] (Investopedia, Economy, n.d.)
[8] (Andrei, 2013, p. 240)

This goal is defined by the five main goals economies try to achieve: full employment, stability, economic growth, efficiency and equity.[9]

Efficiency is considered to be a micro-economic goal, which tries to fulfil the needs of a society to the best possible level with the resources available. This is best executed when limited resources are allocated in a way that fulfils as many needs and wants of a society as possible.[9]

Equity is also a micro-economic goal and concerns itself with the 'fair' distribution of income and wealth. While it is a common view that wealth should be 'fairly' distributed, the definitions of a 'fair' distribution vary. The three main approaches are, the goal of everyone having the same income and wealth, the distribution of income and wealth based on production value and the income and wealth based on needs.[9]

Full Employment is a macro-economic goal, with the objective of utilizing all available resources labour, capital, land, and entrepreneurship to produce goods and services. [9]

Stability a macro-economic goal that is achieved if changes in production, employment and prices are avoided or limited. It is usually rated based on month to month or year to year changes and helps consumers and other economic entities to make long-term assumptions and to plan their finances accordingly. [9]

Economic Growth counts as a macro-economic goal and focuses on the ability of an economy to produce more goods and services over a duration of time. This means that if more goods and services are produced in one year compared to the last year economic growth is achieved. This usually results in improved living standards and less scarcity of goods and services. [9]

While the five goals of mixed economies are widely considered to be desirable, trying to achieve one goal often works against the objective of the others. An example of this could be: "Full Employment and Stability: The Central Bank of Northwest Queoldiolia seeks to promote lower rates of unemployment through expansionary monetary policy. The economy expands, unemployment falls, and full employment is achieved, but inflation emerges from the over-stimulated economy." [9]

In addition to the goals of mixed economies, it is also quite common that economies have more specific goals related to a country or government. Examples for this could be: Solving of environmental issues, upgrading the infrastructure, optimization of the utilized landscape, etc.

2.5. The definition of supply and demand

"Demand defines as a quantity of one individual good (service) that an individual, group or economic entity wishes and is able to acquire (purchase) within a considered period of time."[10]

[9] (AmosWEB Encyclonomic, n.d.)
[10] (Andrei, 2013, p. 150)

Demand can be divided into two main areas: Individual demand, which focuses on the goods and services a single individual wishes to acquire, and market demand, which includes the demands of all economic entities within a market area.

It should be noted that the expected behaviour of the individual demand versus the market demand is, that the individual demand mainly follows the market demand, but can differ for some goods or services. This makes the individual demand more focused on specific people and allows to conclude tests for certain groups of economic entities for example depending on education, income or location.

"Supply is the total amount of a good or service available for purchase at any specified price."[11]

Supply determines:

Price of a good or service:

The current owner or distributor of a good or service will try to achieve the highest possible price for that good or service, while the consumer will try to obtain it at the lowest price. This means that the actual price will be based on the highest price a consumer is willing to pay and the lowest price for which that good or service is available in one economy.

Production cost of a good or service:

If the supply of a good or service is high it is likely that the production process will be improved, which reduces production cost and increases profit.

Competition between economic entities:

Over time competition will result in lower prices for that good or service since more economic entities can compete with each other. Competing for goods and services will reduce the price and a supplier may switch to more profitable products, therefore, reducing the supply of the previous good or service.

2.6. The market

"The market is an actual or nominal place where forces of demand and supply operate, and where buyers and sellers interact (directly or through intermediaries) to trade goods, services, or contracts or instruments, for money or barter.

Markets include mechanisms or means for determining price of the traded item, communicating the price information, facilitating deals and transactions, and effecting distribution. The market for a particular item is made up of existing and potential customers who need it and have the ability and willingness to pay for it."[12]

Based on this definition it can be said that the market is a system based on the interest of potential customers and therefore demand. The prices are based on how many potential customers are willing to pay and are therefore based on supply and demand. This makes this

[11] (Business Dictionary, Definition Supply, n.d.)
[12] (Business Dictionary, Definition Market, n.d.)

system one that is focused on the mutual interest of both the consumers as well as the distributors and in extension of that also of the producers.

This pushes this system into a position, in which the three parties of consumer, distributor and producer have to come to an agreement about how much a good or a service should cost.

This situation allows for conflict between all parties that eventually resolves in a 'fair' price. This price is based on the amount of currency a customer is willing to invest into a good or a service and how much of a good or service a distributor has to sell to justify the production of given good or service. These prices are then further influenced by many factors like prestige and necessity.

Another factor is how much supply and demand differ from each other. If there is more supply than demand the costs of a given good or service will fall since there will be more competition between different distributors for a smaller number of customers. If the demand of a given good or service is greater than the supply, the costs of that good or service will rise, since there is only a limited amount of that good or service and not every consumer is able to obtain it. This results in a race to obtain the given good or service between all the different consumers who want or need it and have the ability and willingness to pay for it.

2.7. Planned economies

"Planed economies or command-based economies are systems where the government, rather than the free market, determines what goods should be produced, how much should be produced and the price at which the goods are offered for sale. It also determines investments and incomes."[13]

This means that the government removes all competition between distributors by controlling all business-relevant factors like production rate and the price of any good or service. This allows a nation to focus its economy on national economic goals at any given point of time. An example of this would be if a nation wants to achieve economic growth.

These economic systems often feature government-owned monopoly business sectors, which are necessary to meet the goals of the national economy. This results in an avoidance of competition in those business sectors. Examples for these businesses usually include financial institutions or utility companies.[13]

The most known problem with this form of economy is the lack of knowledge the central planner can have, since it is almost impossible to predict how much of a product must be produced and how the demand for every product will shape out. The central planner has to adjust the supply to the predictions made for these factors. Another common problem is the necessity of a constantly changing system. The central planner needs to adjust the economic system constantly to meet the goals of the government and all changes need to be communicated to the companies and can only then be realized. This limits this approach to a limited amount of changes for the economic systems over long periods of time. This is, because

[13] (Investopedia, Command Economy, n.d.)

of the time needed to communicate and realize these changes. Resulting in a system that has difficulties with fixing the problems of the previous adjustments for a longer period of time.

2.8. The differences between Market- and Command-Based economies

Market- and command-based economies are the most common forms of economy in our society.

2.8.1. Market-based economies

"Market-based economies allow goods to flow freely through the market, according to supply and demand. This type of economy has a tendency to naturally balance itself. As the prices in one sector for an industry rise due to demand, the money and labour necessary to fill that demand filter to the places where they are needed."[14]

Based on this, it is possible to determine that market-based economies create a positive feedback loop[15] for the production process, in which based on the demand of a good or a service more jobs and tools will be created to speed up the production process. This allows to sell more of a good or a service, which in return allows to spend more on jobs and the development and creation of tools. This automatically stops or declines if the supply of a good or service is equal to the market demand or if the market demand falls below the available supply of a good or service. This opens up space for new demands in the market structure and labour and financial resources are then redirected towards fulfilling these new demands.

2.8.2. Command-based economies

"Command-based economies are dependent on a central political agent, which controls the price and distribution of goods. Supply and demand cannot play out naturally in this system because it is centrally planned, so imbalances are common."[14]

In command-based economies feedback[15] has no effect on the market. This can easily result in problems with money and product distribution. Since it is possible that a good or a service, which is needed by many can only be obtained by a small amount of the population because the set price is too expensive for the others. It also has the tendencies of creating a good or a service in too low quantities. Pushing a come first get first systems, that depending on the way it is managed can result in high waiting periods for obtaining specific goods or services. But the opposite can also be the case: If a good or service is too cheap or too much of a good or service is produced, a large quantity of that good or in case of services time, will be wasted either by the consumer or the producer. It should still be noted that with near perfect insight and short adjustment periods for changes (which can't consistently be obtained in the real world but is possible in virtual environments), prices and quantities could be controlled in a way that could allow command-based economies to function.

[14] (Investopedia, Economy, n.d.)
[15] (Salen & Zimmerman, 2004, p. Chapter 18)

2.8.3. Comparison between both systems

Viewing these two concepts in direct comparison it becomes possible to see that one of the main differences between these two forms of handling economic systems is that market-based economies directly respond to the feedback of the consumers and distributors, while command-based economies won't. This allows market-based economies to automatically readjust themselves, while command-based economies need to be adjusted manually.

That being said, it should also be noted, that properly managed command-based economies have the ability to distribute more resources to goods and services that consumers need rather than goods and services that consumers want allowing for a more optimized flow of resources, since this can be planned in advance. Command-based economies allow to theoretically guarantee that companies can keep producing since resource supply is guaranteed before the production starts.[16]

2.9. Definition of inflation

"Inflation is a quantitative measure of the rate at which the average price level of a basket of selected goods and services in an economy increases over a period of time. Often expressed as a percentage, inflation indicates a decrease in the purchasing power of a nation's currency. As prices rise, they start to impact the general cost of living for the common public and the appropriate monetary authority of the country, like the central bank, then takes the necessary measures to keep inflation within permissible limits and keep the economy running smoothly. Inflation is measured in a variety of ways depending upon the types of goods and services considered, and is the opposite of deflation which indicates a general decline occurring in prices for goods and services when the inflation rate falls below 0 percent."[17]

This means that inflation is defined by the rising amount of currency needed to obtain a good or service over a certain amount of time. So basically if someone would have 10$ and it would be possible to obtain 10 eggs for that amount of money, but that person saves the money and wants to buy eggs 10 years later, but now one egg costs 2$ and that person can only obtain 5 eggs with the 10$ that he or she saved.

The inverted effect of this resolves in a reduced amount of currency needed to obtain a good or service and is called deflation.

The causes of inflation can be divided into three main types: "Demand-pull inflation, cost-push inflation, and built-in inflation"[18], which causes inflation in one or more of the following ways.

[16] (Investopedia, Command Economy, n.d.)
[17] (Investopedia, Inflation, n.d.)

Demand-pull inflation:

This form of inflation happens if the demand for a good or service rises faster than the possibility to supply that good or service. Resulting in higher prices of that good or service. Another way this form of inflation can happen is if the total amount of currency increases, since this forces a good or service to increases its costs to allow it to keep its value.[18]

Cost-pull inflation:

This form of inflation is based on increased production costs, be it the increased costs of labour or resources. These higher production costs must be covered into a higher price for a good or service to allow it to keep its value.[18]

Built-in inflation:

In this case inflation itself pushes inflation. If goods and services become more expensive the labour force needs more wages, which results in the necessity of a higher cost for a good or service as explained in 'Cost-pull inflation'.[18]

2.10. A brief overview of the history of the economy

The Greek meaning of the world economy is household management. The first recorded times of economics as an area of study was by the philosophers in ancient Greece, but the way economics are studied today has its roots in the 18th century in Scotland and France.[19]

At first, studying how people work together and use resources for the production of goods and services was named political economy, and the people who studied this area were called political philosophers.[19]

The Scottish philosopher Adam Smith, wrote in 1776 the famous economic treatise "The Wealth of Nations". He believed that economies come from the pre-historic bartering systems to money and eventually to credit-based economies.[19]

"During the 19th century, technology and the growth of international trade created stronger ties among countries, a process that accelerated into the Great Depression and World War II. After 50 years of the Cold War and the end of the Bretton Woods agreement, the late 20th and early 21st centuries saw renewed globalization of economies."[19]

2.11. The math behind economics

Almost all economic revelations can be translated into mathematical formulas. But many of these formulas struggle to capture the development of a market situation over a long period of time and it is not proven if they can be utilized for game economies. Therefore will this work not include in-depth coverage of economic math but rather refer to economic functions on special occasions to explain certain phenomena documented in some of the created prototypes. To build a more in-depth understanding of the mathematical structure of

[18] (Investopedia, Inflation, n.d.)
[19] (Investopedia, Economy, n.d.)

economic systems “Basic Economics – Economics for all[20]”, “Handbook of Monetary Economics[21]”, and "The stability of models of money and growth with perfect foresight[22]” are recommended places to start.

[20] (Andrei, 2013)
[21] (Friedman & Woodford, 2011)
[22] (Sargent & Wallace, 1972)

3. The financial economy in games

This chapter will focus on how financial economic systems are structured in games and how market, trade, and resource allocation are handled within these systems.

This chapter will offer a general understanding about how entities interact with each other in a virtual economy and explain the differences between the economic systems in real life compared to how most games handle their financial economies. This chapter will also explain why the virtual market has different limitations compared to its real-world counterpart and what problems and solutions can be applied in virtual economies.

This chapter will reference games that utilize commonly used approaches for handling market, trade and resource allocation in games, to showcase how these systems work.

This chapter will be used in later chapters to determine the difference between real world and virtual economies.

3.1. Goals of economies in games

Economies in games serve as ways to allow visualization of progress to the player by showcasing amongst other things how much money or experience was generated during the last play session. But even more so they are a way of giving the player interesting choices about what they want and can acquire. In the case of experience, this could be the decision between different skills the player has to choose from at each level up and in case of money this translates into what items the player can choose from at a merchant. This makes economies resource allocation systems, in which the player has to decide how to acquire more resources and how to spend them. Therefore the first questions that must be answered when thinking about game economies are how a currency can be earned and how the earned currency can be spent.[23]

Considering this the similarities between the economy in games and economy within the real world become apparent. Both concern themselves with how resources are acquired, both strive to perfectly manage the allocation of given resources and both offer incentives to do something based on the current way of how resources are acquired, in the case of the real world this could be the current market situation in a game that could be the currently active quest. But there are also a large number of differences. Ignoring that economies games and the real world have different limitations, which will be covered later in this chapter, the fundamental goal of them is completely different. The real world is concerned with the creation of a system that allows different economic entities to interact profitably with each other to the means of supplying all consumers with the goods and services they need or want. Game economies don't care about any entities other than the players and the economy is not centred on productivity or effectivity but rather a means of handing interesting choices to the player and therefore delivering fun.

[23] (Schell, 2015, pp. 234-235)

To manage this there are a few goals that should be considered by designing an economy for a game:

- Fairness:
  Is it possible to buy items that allow for unfair advantages or make ways of experiencing the game undesirable? Are there ways of obtaining currency in an unfair way?
- Challenge:
  Is it possible to buy items that result in a too low level of difficulty? Is it too hard or too easy to earn currency?
- Choices:
  Are there enough desirable ways to spend and earn currency?
- Chance:
  Is chance or skill the determining factor of how to obtain currency?
- Cooperation:
  In what ways can players work together to buy something in the game or earn currency and what effect does this have on the overall economy?
- Time:
  Does earning currency take too much or not enough time?
- Rewards:
  How does it feel to earn or to spend currency?
- Punishment:
  How do mistakes or setbacks affect the players' ability to earn or spend currency?
- Freedom:
  Can the player buy what they want and earn currency in the way they want?
  [24]

This makes the objective of a virtual economy in games to achieve all of the formerly listed goals for the complete duration of the game. So different from real-world economies full employment, efficiency and equity can be completely ignored and instead a game economy focuses on controlling economic growth depending on the players level of progression, which means to allow the player to experience economic growth through amongst other things a level up, since it is now possible to challenge stronger enemies the player is able to obtain more currency, since these enemies have more valuable items. To combat this the player will need to buy more expensive items to fight against these enemies. Because of this income as well as spendings of the player are increased. The challenge is to maintain stability for all of the previously mentioned goals since they should all be achieved for each level of economic growth the player can have.

[24] (Schell, 2015, p. 235)

3.2. The form of economy that is used in games

Financial game economies are carefully crafted systems that are created by the Game Designer or even a whole team of Game Designers. This places the economic system of most games like the *Borderlands*[25] series, *The Elder Scrolls V: Skyrim*[26] or *Divinity: Original Sin 2*[27] in the area of planned-economies or command-economies. The whole system is predicted and evaluated by the design team, which then adds fixed prices and rewards to the goods and services of a game. This system appears to be a proper way of handling economies in games since by determining how much currency a player is supposed to have at a certain point during the game prices and rewards can be placed at a meaningful level to allow for interesting choices, but this system also harbours many of the limitations and problems that usually come with command-economies.

Relevant limitations of this system are, that this only works as long as the player is either following a linear game flow that allows the designer to accurately predict the amount of currency the player has at a certain point of the playthrough or the limitation that the overall value of goods and services the whole game world offers must be consistent, meaning that the game features different tier layers of goods and services that decide the position of the player progression rather than location-based item additions. This results in merchants offering a large variety of items at once, for the different progression levels a player can achieve and therefore allow the design team to give the player realistic access to goods and services based on the current progression level.

But there are also a number of more severe problems with this system. Starting with how complicated it is to predict a players' behaviour. The player has the option to obtain a lot of currency or a small amount of currency after completing a section of a game, this is heavily dependent on how many goods the player has found during that section. But even if a player has obtained fewer goods during that section it would usually be the best experience for that player if it is still possible to obtain desirable goods from the next merchant in a similar way to the player that has gathered all the goods of the previous game section. But that is not guaranteed by a flat *command-based* economic system.

There are also a number of games that tried different approaches. An example of this is the approach of *Counter Strike: Source*[28] to implement a dynamic weapon price system. *Counter Strike: Source*[28] is a first-person shooter in which players play multiple rounds against each other and obtain currency based on the performance of previous rounds. This currency can be spent to buy equipment for the following rounds. The dynamic weapon price systems analysed how often a piece of equipment was acquired and increased or decreased the price of it

[25] (Gearbox Software)
[26] (Bethesda Game Studios, The Elder Scrolls V: Skyrim, 2011)
[27] (Larina Studios, 2017)
[28] (Valve Corporation, 2004)

accordingly. This resulted in extreme polarities of equipment prices for example 1$ for a Glock and 16.000$ for a Desert Eagle.[29]

Another approach that is not used as often but should still be mentioned is an economy that allows for unrestricted trades between players, which results in a *market-based* economy. An example of how such an economy can be structured is the game *EVE Online*[30]. A more in-depth explanation of the economic system of this game can be found in the article "How to build a robust game economy: Lessons from one of the world's longest running MMOs"[31]

3.3. Currency

Currency in games as in the real world could be anything but is usually chosen based on a number of factors that make it easier to utilize it as a trading tool. The usual approach to determine a good form of currency is to check an object for these qualities:

- It is easily portable
- It has a high-value density
- It is easily divisible
- It is relatively scarce
- It is useful in and of itself beyond facilitating financial transactions

[32]

After a currency is determined the members of a society accept it for goods and services since they can expect that another person will accept it for their goods and services. This works in games, since even if the currency of a game would have no secondary use, the player can always expect an NPC (Non-Player Character) to accept it and can therefore be sure that the lowest amount of value a currency has is equal to the highest value item the player can obtain for that currency from an NPC.

3.4. Are virtual economies in games complete economic systems

To answer this question it is necessary to divide games into two perspectives. The perspective of the player and the perspective of the designer that includes the whole economic system covering all aspects of a game.

The perspective of the player is one of an individual-economy and based on that a micro-economic system that considers the economic system from the view of the player or the character controlled by the player. Based on that, it is possible to determine if the player has to consider all aspects of an economy within the players' individual-economy.

[29] (Johnson, 2009)
[30] (CCP Games, 2003)
[31] (Goh, 2018)
[32] (Azaral, 2012)

An economic system is defined as a large set of inter-related production and consumption activities based on which economic entities decide how resources should be allocated.[33] This means for the players' individual-economy to be considered an economic system, the player must have access to resources that need to be allocated and the player must have an incentive to produce and consume goods or services.

In game titles like the *Borderlands*[34] series, *The Elder Scrolls V: Skyrim*[35] or *Divinity: Original Sin 2*[36], which all utilize traditional and often used financial economy systems of games it becomes easy to see that the player has the means and the intention of producing goods and to complete services, while producing goods cover everything from crafted products to objects obtained from enemies or found within the game world and services are based on tasks or quests the player obtains and fulfils from NPCs (Non-Player Characters). The services the player completes for the NPCs offer rewards that can be used or sold. The same goes for the goods the player finds or obtains from enemies. This gives the player a number of resources to allocate to specific areas since goods can be used, consumed or sold, which creates currency that can be invested in other goods by buying them from merchants or investing it in services NPCs can offer to the player like repairing equipment, gaining short-term buffs or completing a task within the game world, like distracting a guard.

Based on this it can be said that the player as an individual has all necessary aspects to be viewed as an economic entity and fulfils therefore all necessary factors that allow to view the players' perspective as a micro-economic system.

But if the perspective of the designer and the complete economic system of the game meaning the macro-economic system of the game is tested in the same way, the results are usually different. While the components of the economic system offer the existence of services and goods by NPCs merchants and NPCs that can do tasks for the player as explained before. The economic system has no need to allocate resources since it simply has all the resources it needs (If the design wants it). Merchants can have unlimited or regenerating amounts of money and items and characters in the game can simply have goods. This is valid for games with respawning enemies without respawning the amount of goods owned by characters in the game world is fixed and therefore follow the rules of resource allocation.

The result of this is that the economic systems commonly used in games offer a complete economic system for the micro-economic system of the player, but not for the macro-economic system of the whole economic system that covers all aspects of a game.

[33] (Andrei, 2013)
[34] (Gearbox Software)
[35] (Bethesda Game Studios, The Elder Scrolls V: Skyrim, 2011)
[36] (Larina Studios, 2017)

3.5. Trading with Non-Player Characters

Non-Player Character or short NPCs are often a component of the trading system of a game. Allowing the player to exchange items found during the play sessions for currency or currency for items the player desires. More often than not this merchant character will have access to an unlimited or regenerating amount of currency and buy everything from the player regardless of its own needs. This in addition to the usual fixed price value of items allows the player to obtain an infinite amount of currency as long as it is possible to obtain an infinite amount of any item. This means that as long as a game allows for example to kill a respawning enemy repeatedly, it becomes possible for the player to have a not predictable amount of currency at any point in the game.

3.6. The finite amount of supply in games

At first glance, the previous statements make it appear that games have an infinite amount of supply, which is correct for each individual item since it is possible to create an infinite amount of copies. But supply in games is limited in a different way.

Supply in games is limited by the number of different items a player can and wants to obtain. While in the real world more desirable goods and services are offered than most consumers are able to obtain, games often have a quite limited amount of choices that they can hand to their customers. Players are usually able to obtain more currency than the amount of goods or services offered. If a game intends further development through for example continuous updates or DLC (Downloadable Content) it is possible that some players didn’t have access to desirable items for some time and have therefore acquired large amounts of currency, allowing them to obtain the new content more quickly, which then results in a more extreme case of this situation for the next update or DLC.

4. Differences and similarities between virtual and real-world economic systems

In this chapter, the statements of the previous chapters will be compared to allow for an understanding of how virtual and real-world economies compare to each other.

4.1. Common trades of economic systems

Economic systems be it a virtual system or one that exists within the real word, concern themselves with the relationship between consumer and distributer, how these two entities trade with each other and how resources are allocated.[37]

Both systems are structured in a way that allows them to pursue certain economic goals. Stability and economic growth (In games for the player entity and in the real world for the macro-economic system)[38] are two goals both systems usually have in common.

It is also possible to identify certain economic systems within both use cases and they can usually be determined using the same questions. This allows, for example, to consider if an economic system be it in a game or the real world can be considered a planned economy or a market-driven economy.

4.2. Differences between Economic Systems

The first and probably most important differences between economies in games and the real world is that while stability and economic growth (In games for the player entity and in the real world for the macro-economic system)[38] are goals that both economic systems have in common, their main objective is completely different. This means that the economic systems of the real world concern themselves mainly with the objective to create a 'fair' way of resource distribution, an overall growth on a macro-economic level, a stable price for goods and services, the utilisation of all available resources and the most effective use of all resources available.[38] While economic systems in games have the objective to deliver interesting choices to the player[39] making stability and economic growth more side goals that are advantageous for the actual objectives.

Another difference is the way resources are limited within these systems. In real-world economic systems every resource is limited and a decision must be made about how that resource is used. Contrarily in-game economies, every resource can at least theoretically exist for an almost infinite amount of times since everything can be copied and simply exists twice or trice. But game economies are limited in another way. While in the real world many people work on the creation of new or different things, games have usually only a limited team that creates only a limited variety of different goods that can be obtained within the game. This

[37] (Investopedia, Command Economy, n.d.)
[38] (AmosWEB Encyclonomic, n.d.)
[39] (Schell, 2015, p. 235)

makes resource limitation in games more a problem of consumer choice than a resource quantity limitation.

In the real world all entities are a concern for an economic system, but in games, all players and the system exist separately from each other. Allowing games to ignore the demands of all NPCs that exist within the system and by doing so to treat them as a collective entity that does not have any needs.

In games, the players interact with a system that has, at least theoretically, an infinite amount of supply. It is therefore possible for that system to engage in all trades that a player asks for. If the player obtains a good or currency from that system the total amount of that good or currency within the game world becomes higher. If the player gives a good or currency to the system the total amount of that good or currency within the game word becomes lower. Comparing this to trade in the real world, one comes to realize that while different entities engage in trade the total amount of goods and currency always stays the same. The only way of increasing or reducing the amount of a good or currency in the real world is by breaking something or producing something, both of which generally result in the creation or exhaustion of other resources.

4.3. What does this mean for game economies

This means that game economies have more freedom in how an economy can be managed since many of the known limitations from real-world do not apply. But it also shows that economies in games have goals that can be problematic to combine with the approaches for solving basic economic problems in the real world.

5. The utilisation of single player role play games to showcase how economic systems work in games

This chapter will quickly clarify, why this work will utilize single player role play games (in short RPGs) to explain how economic systems function in games.

5.1. Economic systems of single-player RPGs as a baseline

If the economic system, which concerns itself with trade and finances, of a game is viewed on its basic level it becomes apparent that these systems are very similar in most genres. They usually revolve around a simple way for the player to earn and to spend currency. Out of all genres, single player RPGs allow for the most visually relatable explanations and showcases. Because of this, will RPGs be the genre this work utilizes to explain economic systems in games.

Economic systems will usually allow to be translated to games of other genres and this work will showcase how this is done.

The existence of multiplayer does not change how the basic economic system of a game works but rather expand upon it, by adding all possible economic interaction players have to the system.[40] This means that problems which exist for the basic system will further exist for the same system for a multiplayer game, but the effects will spread to the other players. For this reason will this work will not cover multiplayer games. But it should be mentioned that if the economic systems of multiplayer games are viewed separately, problems with the economic player to player interaction could be adjusted by the designer, since total control of how players obtain goods or currency and how they are allowed to interact with them does exist. This makes the most common problems usually part of the core system.

[40] (Azaral, 2012)

6. Utilizing *Machinations*[41] to create economy prototypes for games

This chapter will offer an explanation about what *Machinations*[41] is and iterate on the advantages it brings for planning economic systems and showcasing them in understandable manners.

6.1. Introduction to *Machinations*[41]

Machinations[41] is a tool for creating a visual language that utilizes diagrams to communicate its information. This tool has its focus on game systems and the internal economic structure of these systems and allows to model functional economies that can be tested and balanced. This is done by iterating on economy prototypes that showcase how entities interact with the system or how the system interacts within itself in real-time.

Machinations[41] offers a graphical extension to spreadsheets and can be utilized to explain the results more easily to a broader audience. In addition to that, allows *Machinations*[41] for a more understandable workflow and therefore for faster iterations and evaluations of the created and tested systems.

6.2. Reasons for this work to utilize *Machinations*[41]

Machinations[41] allows this work to create multiple approaches for adjustments to already existing economic systems in games and iterate on them based on the problems that come apparent while evaluating the real-time simulations of the approach prototypes.

Machinations[41] allows to export the data for marked variables. The data is saved for every time-step of the real-time simulation and can easily be transferred to spreadsheet programs like *Microsoft Excel*[42]. This allows to quickly collect, save and work with the prototype data.

This tool is capable of running multiple samples of a specific approach in a short period of time. This enables this work to run on a decently sized sample size that gives the results an acceptable level of credibility.

Because of the way *Machinations*[41] is structured, the created systems can quickly be altered, which allows this work to go multiple iterations deep into the functionalities of specific approaches.

As an additional advantage allows this software to ease the explanation of how these prototypes function, since it offers an understandable visual representation of a system that can be viewed step by step.

[41] (Dormans, n.d.)
[42] (Microsoft)

6.3. Reasons for game development teams in general to utilize *Machinations*[43]

Machinations[43] adds many possibilities to the game creation process. Most of them are not new, but this tool allows to realize them faster and more visually, which makes it simpler to explain these ideas to the team or publisher while also reducing the probability for human error. This comes through the fact that the visual representation allows to understand problems in a logical way compared to the sole mathematical way most spreadsheet programs offer and through the possibility for other members of a team to spot problems easier.

Machinations[43] enables the designer to test the created economic system in wide sample sizes before large scale playtesting is possible. This makes it possible to spot problems a game could have before the main development process has started.

This tool works well with many already utilized tools and can therefore often extend the game development process, without having a negative effect on established pipelines.

6.4. More about how *Machinations*[43] works and how to use it

Machinations[43] is a well-documented tool. The book "Game Mechanics Advanced Game Design"[44] showcases how to utilize it from a basic to advanced level. "Machinations: A New Way to Design Game Mechanics" [45] is a GDC talk of both authors that covers a basic introduction of how the tool is used and what it can be used for. A documentation for the tool can be found at https://docs.machinations.io/[46].

[43] (Dormans, n.d.)
[44] (Adams & Dormans, Game Mechanics Advanced Game Design, 2012)
[45] (Adams & Dormans, Machinations: A New Way to Design Game Mechanics, 2012)
[46] (Dana & Gheza, n.d.)

7. Creation of economy prototypes with the tool *Machinations*[47]

This chapter will showcase a step by step example of how to analyse an existing economic system with *Machinations*[47] and utilize it to showcase how a given economic system could be changed to test how it would behave under new conditions. After that this chapter will explain how to evaluate these test and how one could use the evaluations of the tests to build upon it to get to a certain result.

7.1. Creating *Machination*[47] prototypes from existing games

To showcase how one can breakdown the economic system of a game and transform it into a *Machinations*[47] prototype three different games have been chosen to indicate that the approach of doing so can be translated to almost every economic system found in games. The created prototypes will utilize fake numbers and will not show a precise example of how economic interactions in these games are concluded, but rather work as an indicator of how these systems work on a basic level. That being said it should be possible to add correct numbers to systems created by this approach to create systems that allow to be utilized as balancing tools for almost every economic system created in a game.

The first game that will be utilized as an example of how to break down a game to its economic structure will be the *Borderlands*[48] series. To do this, it is important to consider how in-game economic systems work as explained in the former chapter 'The financial economy in games'. Based on which it can be said that games should be evaluated form the micro-economic perspective of the players, since all forms of macro-economic behaviour can be changed by the designer without limitations (unless a game intents to create a whole macro-economic system that effects all other game systems like reward-systems or 'NPC'-merchants). Taking this into account, it becomes apparent that the micro-economic system of almost every game is concerned with how a player accesses currency and how the player spends currency. So to analyse how the economic system if a game works one starts by listing all the ways a player earns and loses currency or objects that can be turned into currency.

In the case of the *Borderlands*[48] series this would be the constant stream of currency gain from looting dead enemies and chests, the income generated from quest rewards and the currency generated by selling unneeded objects. The amounts of value lost by buying new equipment and the ammunition/health needed to fulfil certain tasks and the penalty the player has to pay in case of death. This makes it a prototype for showing simplified version of the economic system of the *Borderlands*[48] series look like **Figure 1**, which showcases the constant flow of income, of items and currency, the player has while playing the game. This prototype visualizes ways a player can lose and earn currency and how selling and buying items effects the players' current amount for currency and items. It also features a randomly generated skill-level that

[47] (Dormans, n.d.)
[48] (Gearbox Software)

effects how often or how much currency the player loses in certain situations and increases the income and costs depending on the players' level. This system could already be utilized to balance how much income the player should generate and how much the player should have to spend on each level.

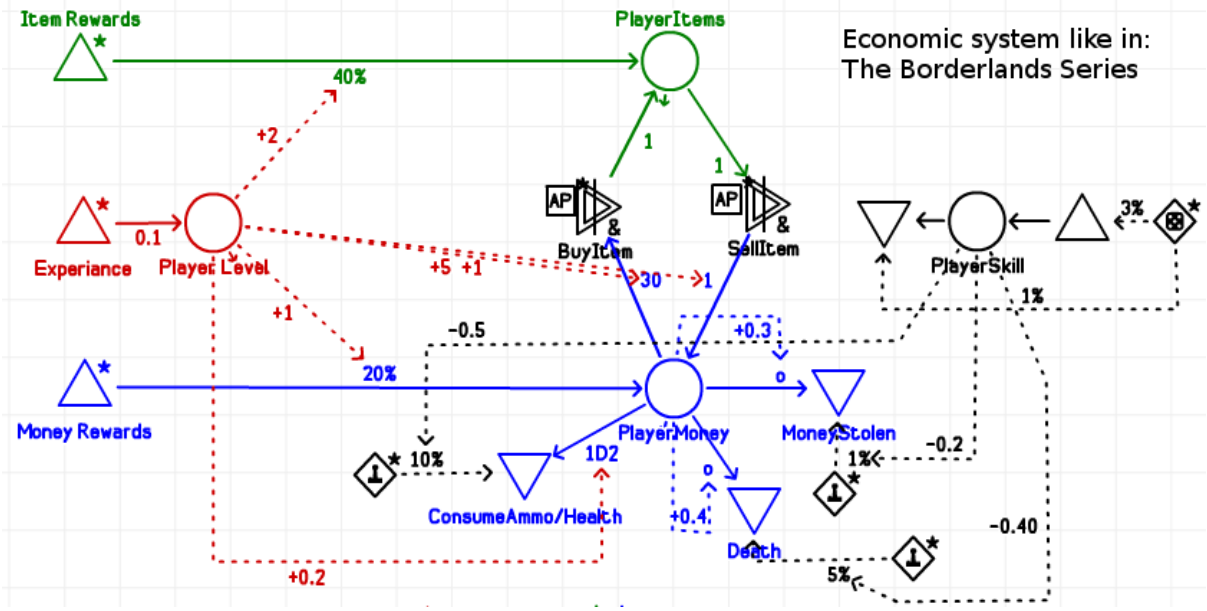

Figure 1

ID	Player Level 1	Player Money 1	Player Items 1	Player Level 2	Player Money 2	Player Items 2	Player Level 3	Player Money 3	Player Items 3
MAX	99	2470	30	99	3749	30	99	2677	30
MEAN	49.00598802	495.1277445	19.24750499	49.00598802	663.7634731	19.41716567	49.00598802	438.4171657	19.37924152
MEDIAN	49	390	28	49	406.5	28	49	289.5	28
VARIANCE S	837.0688952	189953.3643	162.2983204	837.0688952	548724.7941	161.917707	837.0688952	190409.3782	159.8100781
MODE	0	0	28	0	0	28	0	0	28

MAX ITEMS	30
MEAN ITEMS	19.20846307
MAX MONEY	4496
MEAN MONEY	457.2302466

Figure 2

The economic system of *Divinity: Original Sin 2*[49] has similar ways for the player to obtain currency and goods. There is a constant stream of income based on quest rewards and loot. The main way of forcing the player to spend valuables is by creating a situation in which the player is forced to utilize consumable items. The other main approach this game uses to remove currency from the player is by selling desirable items that need to be replaced after a certain amount of progress. Other than this the game also features an increased income and cost curve based on game progression and allows the player to reduce the amount of consumables needed based on the players' skill level. The big difference between *Divinity: Original Sin 2*[49] and the *Borderlands*[50] series is that enemies won't respawn. This creates a situation in which the player is unable to generate an infinite amount of currency and is therefore forced to decide between a maximum of buyable items that can be obtained by the total amount of currency the player is able to obtain. The NPC merchants themselves have regenerating amounts of currency and items, which allows the player to always sell unneeded goods to them. Another difference is that *Divinity: Original Sin 2*[49] has the option to invest skill points into a bartering ability that reduces all prices for items NPC-merchants offer and

[49] (Larina Studios, 2017)
[50] (Gearbox Software)

increases the amount of currency these merchants give the player for goods. It is also possible to steal goods and currency from each NPC once. Handing the player access to an additional, but also not infinite, option of generating income. All this can be seen in **Figure 3.**

At this point an important disclaimer must be made: *Divinity: Original Sin 2*[51] is a game with a very definitive ending. If it were not for that this type of economic system is very likely to run out of resources it can hand to the player. This game avoids doing so by leading players towards different areas and offers new locations constantly, since unless new developments are introduced to an area or the player has new options, old areas are no longer usable for the player, since all tasks and other ways of generating game progress are already exhausted.

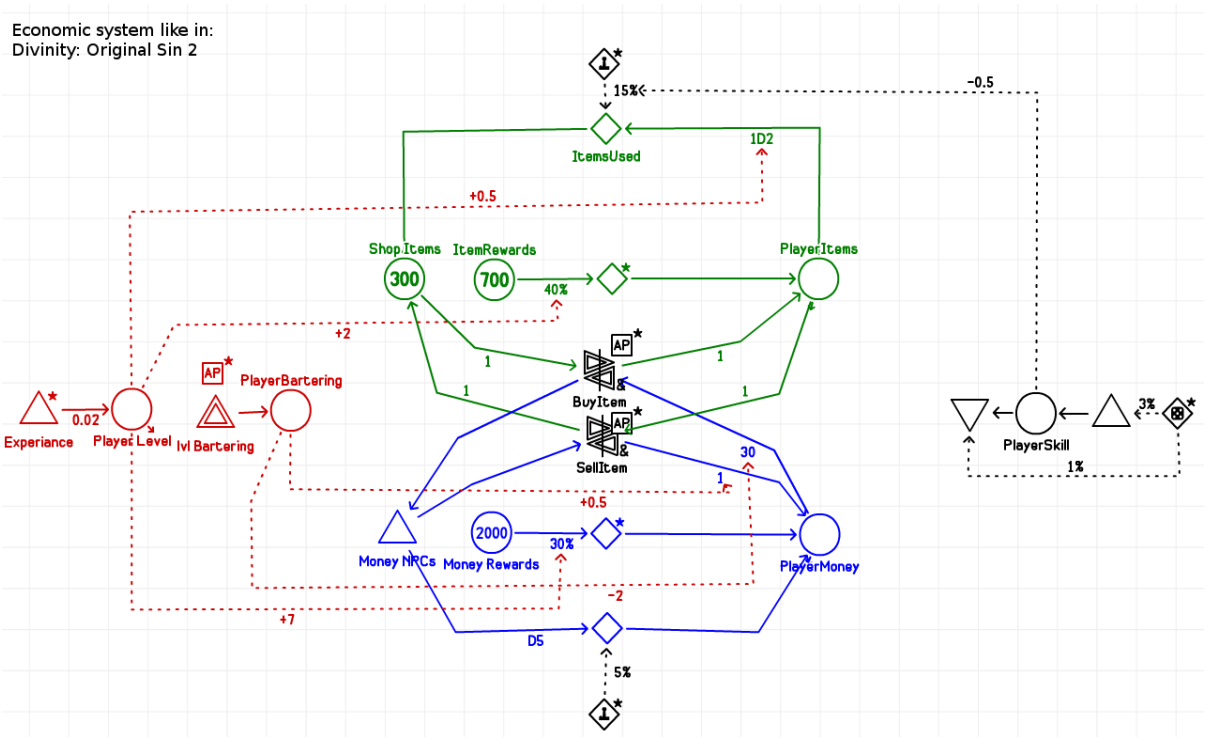

Figure 3

ID	Player Level 1	Player Money 1	Player Items 1	Player Level 2	Player Money 2	Player Items 2	Player Level 3	Player Money 3	Player Items 3
MAX	19	295	33	19	337	27	19	349	52
MEAN	9.424151697	90.15169661	6.53493014	9.424151697	90.20558882	7.580838323	9.424151697	135.6387226	8.00499002
MEDIAN	9	55	4	9	65	6	9	133	3
VARIANCE S	33.39134418	7524.012929	40.73853891	33.39134418	6040.421227	38.48946263	33.39134418	8680.033184	124.888087
MODE	0	0	1	0	0	3	0	0	2

MAX ITEMS	99
MEAN ITEMS	7.628043912
MAX MONEY	770
MEAN MONEY	106.4766628

Figure 4

In *The Elder Scrolls V: Skyrim*[52] the economic system also offers a similar approach to the other two games. The player has a constant stream of income that mainly consists of quest rewards and the loot found in the game. The income and costs increase with game progression. The player has also access to a bartering skill that similar to *Divinity: Original Sin 2*[52] allows the player to reduce the cost of items bought from NPC-merchants and increase the income

[51] (Larina Studios, 2017)
[52] (Bethesda Game Studios, The Elder Scrolls V: Skyrim, 2011)

generated from selling goods. NPC-merchants also have regenerating amounts of currency and items, in a way that is comparable to *Divinity: Original Sin 2*[53]. But unlike *Divinity: Original Sin 2*[53] *The Elder Scrolls V: Skyrim*[54] features respawning enemies in a similar way to the *Borderlands*[55] series. This allows for an infinite amount of currency generation for the player. The main approaches to remove currency from the player, besides the trade disadvantage from buying and selling goods to an NPC-merchant, are the player consuming items that had to be found or bought before and the possibility that the player gets robbed by a thief or bandit. Both of these events can be avoided or at least reduced, if the player is skilled enough. A visualisation of this economic system can be found in **Figure 5**.

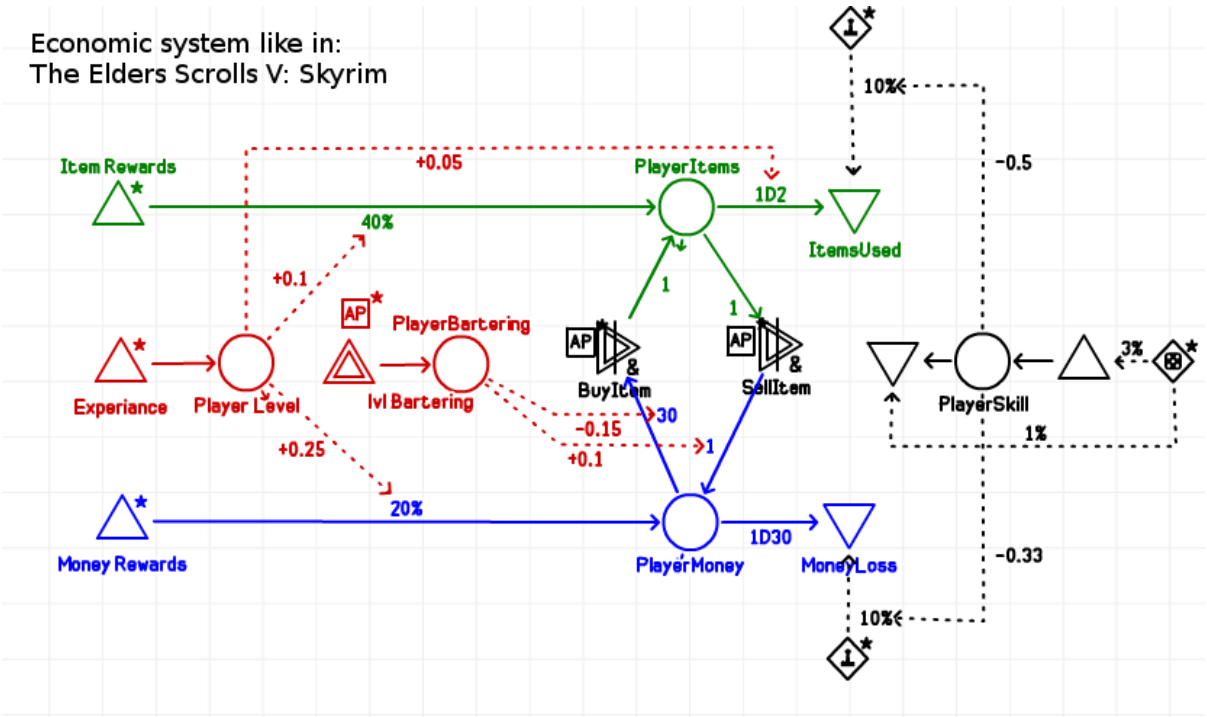

Figure 5

ID	Player Level 1	Player Money 1	Player Items 1	Player Level 2	Player Money 2	Player Items 2	Player Level 3	Player Money 3	Player Items 3
MAX	1000	351	78	1000	466	120	1000	814	109
MEAN	499.500998	51.22055888	14.26347305	499.500998	91.70259481	22.58882236	499.500998	143.2095808	19.10479042
MEDIAN	499.5	22	6	499.5	29	11	499.5	22	7
VARIANCE S	83749.501	5595.90635	290.7377054	83749.501	14000.30507	760.827767	83749.501	48083.60438	649.7702268
MODE	0	0	0	0	0	1	0	0	1

MAX ITEMS	316
MEAN ITEMS	22.17899202
MAX MONEY	1125
MEAN MONEY	80.13606121

Figure 6

7.2. Comparing economic structures of games with each other

If the three prototypes of the economic systems described in the 'Creating *Machination*[47] prototypes from existing games' section of this work are compared to each other by tracing

[53] (Larina Studios, 2017)
[54] (Bethesda Game Studios, The Elder Scrolls V: Skyrim, 2011)
[55] (Gearbox Software)

the values of 'Player Level', 'PlayerMoney' and 'PlayerItems' for multiple, which can be seen in **Figure 7**, **Figure 8** and **Figure 9** common behaviours become apparent. 'Player Level' increases in all three examples for each iteration in the same way, which is the logical behaviour, since 'Player Level' is utilized to measure game progression, which has a fixed development in the created prototypes. 'PlayerMoney' builds itself up and then decreases in chunks throughout the testing period, but the average amount increases over time. This happens because the simulated players spend chunks of their earned currency to purchase items or loose chunks from specific events like death. The overall increase in currency relates to the scaling amount of income being out of sync with the scaling amount of required spendings. 'PlayerItems' behave very similar to 'PlayerMoney' but the overall build-up ratio and strength of the item decreasing chunks is more stable. None the less features 'PlayerItems' a tendency to increase over time. This is likely because of the value difference between one average item and one instance of the chosen currency.

If this behaviour is compared to how a player interacts with the economic system of a game, it becomes possible to connect in-game activities like looting or experience gain with the option of doing tasks that reward the player. Doing so allows the player to grow in power resulting in accomplishing the same tasks faster or accessing new areas with higher amounts of loot. The effect that this has on the economic system of a game is represented in the prototypes shown in **Figure 1**, **Figure 3** and **Figure 5**. This allows a Game Designer to theoretically balance a game economy in a way that leads to players earning and spending an equal amount of currency and therefore a stable economic system. The problem with that is that it is almost impossible to predict a players' spending behaviour over a long period of time, unless it is in some way forced by the game. This explains why balancing a games economic system is a good way of tightening the control of the overall income rate of a player. But it is not enough to control the amount of currency a player has access to at any given moment while playing a game. If this form of control is desirable for a game it becomes apparent, that the economic system as a whole needs to be adjusted in a way that allows the system to either force or incentivise options of gaining or spending currency. These options don't necessarily need to speed up or slow down player progress but they should be something that is desirable to a player and improve the overall play experience compared to a system without these elements.

More precise information about the results of the test with the simplified economic system of the games *The Elder Scrolls V: Skyrim*[56], the *Borderlands*[57] series and *Divinity: Original Sin 2*[58] can be found at https://philippstenger.com/wp-content/uploads/2019/02/BaseSystems_ExcelDocumentation.7z

[56] (Bethesda Game Studios, The Elder Scrolls V: Skyrim, 2011)
[57] (Gearbox Software)
[58] (Larina Studios, 2017)

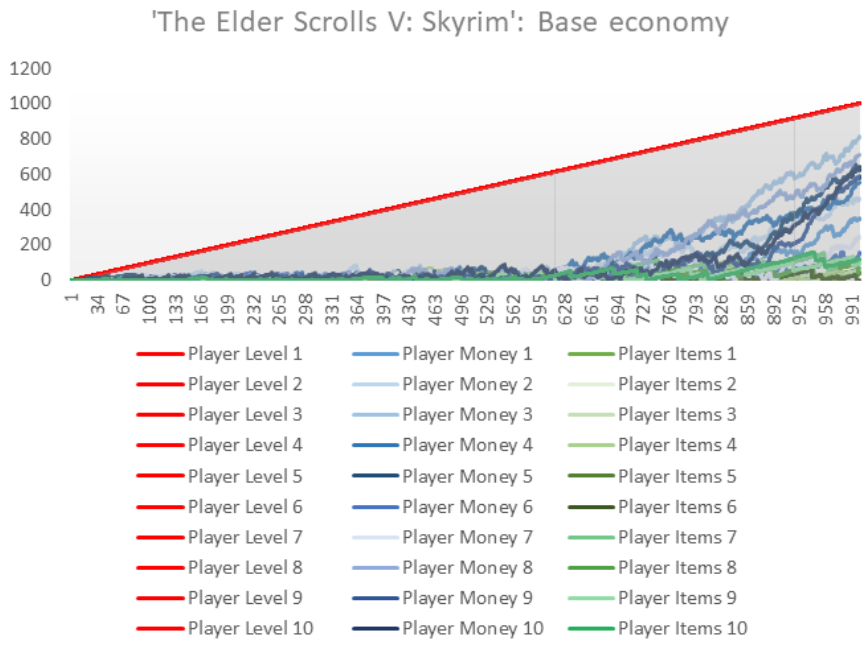

Figure 7

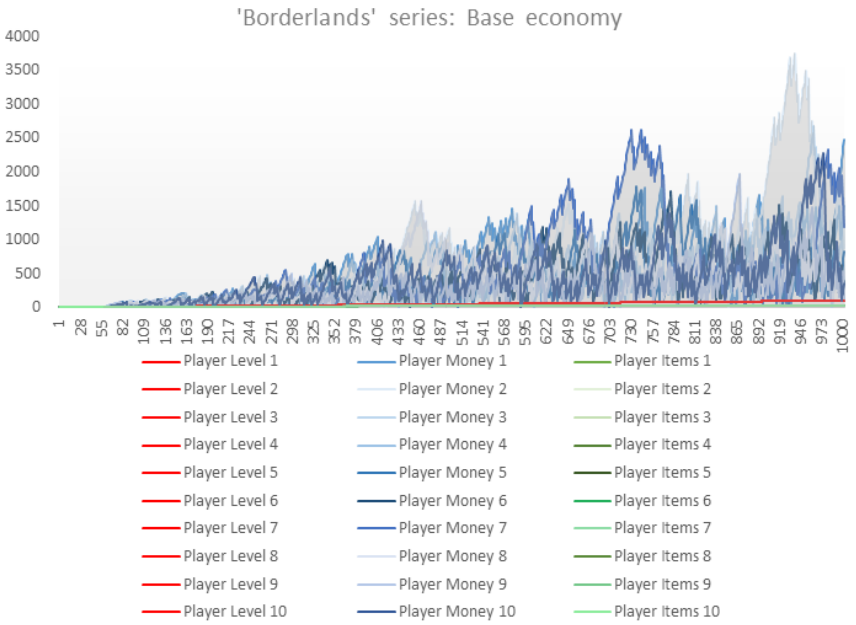

Figure 8

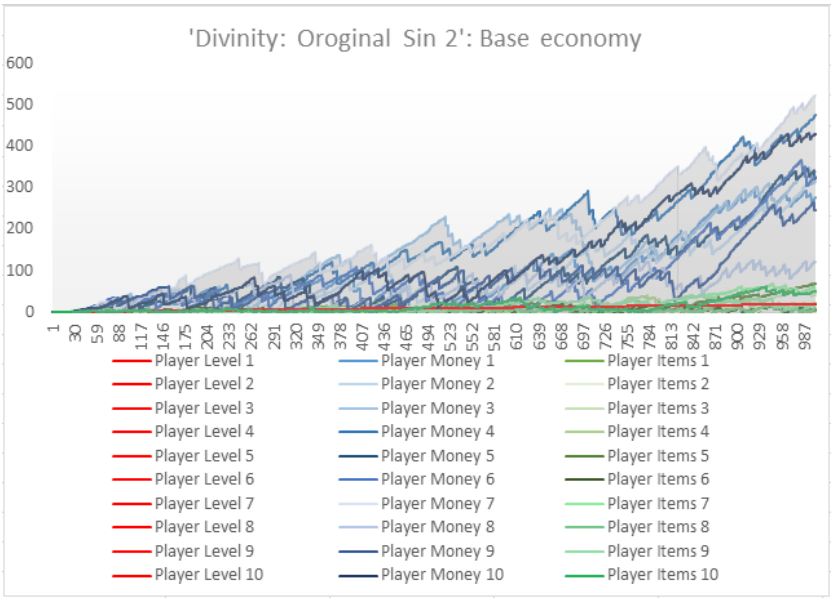

Figure 9

7.3. Prototype description

The following sections will focus on the testing of different approaches with the goal of adjusting the ratio in which the total amounts of player possessions increases over time and how a desired/fixed amount of player possessions could be achieved for an extended period of time. These approaches are not straight forward solutions, but rather a showcase about how someone can start to utilize the tool Machinations[59] to direct an economic system towards a specific economic goal and how to test the system for achieving desired effects and what unexpected problems it may create.

7.3.1. The goals for the prototypes

As already stated, the objective for the prototypes will be the creation of approaches that are able to stabilize an economic system in a way that the average of valuables in possession of each player becomes more consistent and more predictable. By evaluating the data found in https://philippstenger.com/wp-content/uploads/2019/02/BaseSystems_ExcelDocumentation.7z two values and one behaviour can be viewed as the defining point of a stable economic system.

The first of which is the mean of currency and items a player has during its playthrough. For the prototypes created in this thesis, this will be limited to the mean of currency and goods a player has within a limited amount of game progression. If the mean is similar between multiple players the expected result in the game is that players are likely to obtain similar amounts of currency and items and spend similar amounts of currency and items in similar periods of time. The strength with which the amount of currency and items differs from the mean at each step of progression can be calculated by utilizing the sample variance of all steps

[59] (Dormans, n.d.)

of progression. It is possible, that different spending behaviours like saving up currency and then purchase multiple items at once can heavily influence this way of evaluation of the stability of the economic system. This means that the mean value of currency and items shows the average amount of currency and items a player obtains and spends in certain game progression intervals and with that demonstrate the average spending behaviour of players. This makes this value an effective method to determine if players use their earned currency and items effectively and if the game offers enough possibilities and necessities to spend the earned currency or to utilize collected items. This can be determined based on having similar means across multiple playthroughs, while also considering the number of extreme cases. An economic system with similar means and a low amount of extreme cases can be considered stable and an economic system with fluctuating means and a large number of extreme cases can be considered unstable.

The second important value to consider is the maximum of currency and goods a player is able to obtain during one playtrough. For the prototypes created in this work this will be limited to the maximum amount of currency and goods a player is able to obtain within a limited amount of game progression. If the maximum amount of currency and goods in a game is high it likely translates to the fact that the game offers too much currency and items to the player, has not enough or too cheap ways for spending the earned currency or only offers uninteresting or unnecessary ways and situations to spend or use currency and items. Another possibility is that the economic system of a game features increasing amounts of income depending on the players’ progression in which case the maximum amount of currency and items at a certain level of progression must be measured. By measuring the maximum amount of currency and items players have, the same problem that was mentioned for the mean also exist. Because of that, the spending behaviours of players will also heavily affect the results of this test, since players that save up more currency and spend it in larger chunks are not necessarily able to obtain more during the same level of progression. As a consequence, comparing the mean of currency and items to the maximum value shows the maximum amount of currency and items a player is able to obtain during a certain game progression interval and with that demonstrate the maximum income potential of a player. That being said, the maximum amount of currency is a good value to measure how often and in which ration related to the players’ income the need or wish to spend obtained currency or items arises and if the game has enough ways to fulfil that need or wish. This can be determined based on having similar maximums across multiple playthroughs, while also showcasing the number of extreme cases. An economic system with similar maximums and a low amount of extreme cases can then be considered stable and an economic system with fluctuating maximums and a large number of extreme cases can then be considered unstable and therefore unpredictable.

The behaviour that is important for the definition of a stable economic system is the overall trend of mean and maximum currency and items on specific levels of progression. This showcases how much currency and items a player has at each point of progression during a playthrough compared to all the other points of progression during a playthrough. For the prototypes created in this work only a limited amount of points of progression during a playthrough are listed. Evaluating the behaviour of the in this way collected data allows a

translation to in-game expectations. An example for this is the higher or lower income and spending's between different progression levels, which are confirmed if the total amount of currency and items increases or falls but the percentage of how much of the gained currency and items are spent by the player stays the same. Another example is that the balance between income and spending's may vary between different levels of progression. This is usually readable if a player obtains currency and items faster or slower on different progression levels compared to others, even so the spending habits are the same, or vice versa. By measuring these behaviours spending habits of players must also be taken into account evaluating to the maximum and mean of the currency gives no direct feedback about the possibility that a player collects currency and items for multiple progression levels and spends it all at once. In this case the trend for all affected levels of progression is measured in comparison to each other, but the overall behaviour can still be compared across multiple playthroughs. This behaviour can be utilized to determine the overall economic growth the player entity receives between different levels of progression, if economic growth exists within one level of progression or how the income and spending's work on different levels of progression compared to each other. This can be explained base on the increase or fall of the overall income and spendings a player has on different levels of progression, the increase or fall of income and spendings within one level of progression or a percentage based change between income and spendings. An overall increase of income and spending on different levels of progression showcases economic growth of the player entity, while an overall fall shows the opposite. As long as the percentage between income and spending stays the same the economic system can still be considered stable. Having the overall income and spendings rise or fall between progression levels usually translates to desired or undesired imbalances within the game, an example for this would be enemies that offer more loot than other enemies on the same progression level. Another way this could happen is if there are ways for a player to improve something that is not tracked by the progression level. An example for this would be a progression level that tracks a player's in-game level, but it is also possible to obtain equipment that allows to complete the tasks in one progression level faster. If the percentage between income and spendings changes slightly within one progression level it is usually an indicator that the game guides the player by separating different objectives to not overwhelm the player with too many new things at once, but still allowing the players to choose what they what to obtain first. Having missions that are focused on obtaining a special skill for a character compared to missions that are focused on obtaining currency or items are a good example for this. Large differences between income and spending for multiple levels of progression is most likely an indicator for an unstable economic system.

7.3.2. The approach for the creation of the economy prototypes

All prototypes are created utilizing the tool *Machinations*[60] and represent simplified versions of the economic systems of the games *Divinity: Original Sin 2*[61] the *Borderlands*[62] series and

[60] (Dormans, n.d.)
[61] (Larina Studios, 2017)
[62] (Gearbox Software)

The Elder Scrolls V: Skyrim[63]. These prototypes will utilize fake numbers to showcase how the systems work but do not represent the actual values of the chosen economic systems. That being said it is possible for the systems to be translated to the readers' own games by inserting the actual values which will allow to predict and balance ones' in-game economy.

After the explanation of how a game is reduced to a simplified version of its economic system this work will go more in depth about how an economic system can be adjusted to fulfil a specific goal. This will be done by changing the economic system of *The Elder Scrolls V: Skyrim*[63] with the goal of creating a higher level of economic stability. To achieve this, multiple approaches directed towards that goal will be created and evaluated. Promising approaches will then be improved over multiple iterations, while unsuccessful approaches will be dismissed. After a number of iterations the last promising approaches will be compared to each other and evaluated based on their reliability, use cases and potential problems. To evaluate these prototypes the data values of how much currency and items the player owns over a period of time will be collected in a sample size of 100 for each approach. The data generated this way is then compared between different approaches to determine how the stability of the economic system as a whole changes and how extreme cases are affected. Stability is defined as similar values for mean, median and a low sample variance across multiple playthroughs. Extreme cases are defined by their strength, which references to the total amount of currency or items at any point, the higher the value the stronger the extreme case. The important factors to evaluate the extreme cases for the approaches are their strength and how often extreme cases occur.

This whole process will be documented and explained in a way that allows to utilize this method for other games.

7.3.3. Prototype limitations

The prototypes created for this work have several shortcomings. The first of which is that the measurement duration of all prototypes is limited to a certain progression level. This allows to assume if a system has the expected results or not but does not confirm if problems are avoided on a later progression level. This can result in problems if a game adds more levels of progress later on.

Another limitation is, that all prototypes are strictly focused on the economic perspective of the system. It is important to understand that good solutions for an economically balanced system can contradiction themselves with the desired effects and reasons an economic system is added to the game in the first place. This makes it necessary to understand why an approach can work for some games but not for others.

The last and most problematic limitation is, that these prototypes are focused on creating approaches that adjust the economic system of a game based on probability-based player decisions. But real players can be different. If a player discovers a dominant, or at least a good, strategy of achieving economic growth many others will follow. This results in general

[63] (Bethesda Game Studios, The Elder Scrolls V: Skyrim, 2011)

economic behaviour that is more focused a successful strategies than a focus an all strategies. In addition to that it is likely that players come up with ways to interact with the game that were not anticipated. These new ways are not documented within the prototypes and therefore neither tested nor evaluated. Based on this it can be said that it is almost impossible to predict the behaviour of a single player within a large amount of players and it is possible for that single player to influence the others. This can result in the majority of player behaving in an unpredicted way.

Despite these limitations these prototypes are a good way to get a first impression for the workings of a games economic system and give designers a good option to balance it. But they can’t guaranty that the system works outside of the tested progression area, must be evaluated early to exclude approaches that won’t align with the design goals of the economic system and they don’t replace playtesting but rather give an extra layer to test the feedback received from playtesting in a larger scale, but with less reliable results. If a designer keeps these shortcomings in mind these prototypes can become a great tool to make better games.

7.4. Prototype documentation

The documentation of all prototypes created for this work. All documentations are divided in a general description of the approach and its purpose, an explanation for the technical realisation and an evaluation of the collected data created by running multiple tests with one prototype.

7.4.1. Iteration 1: Additional purchases

The first approach that tries to stabilize the economic system of a *The Elder Scrolls V: Skyrim*[64] like game will be based on additional options of purchasable items for players. These extra items can be bought for high prices and are quickly producible by the developers. This approach can be viewed as a well-planned money sink that allows developers to continuously add items to the game. This has the goal of adding more options than a player is able to obtain, creating a high quantity of desirable items, similar to the real world, which offers more things than most people can obtain. These items will mainly consist of colour selections for items additional skins and consumables and will therefore not lead to further economic growth. But these additional purchases can also be considered totally optional which can result in a selection of players that won't buy them. **Figure 10** shows the prototype for this approach.

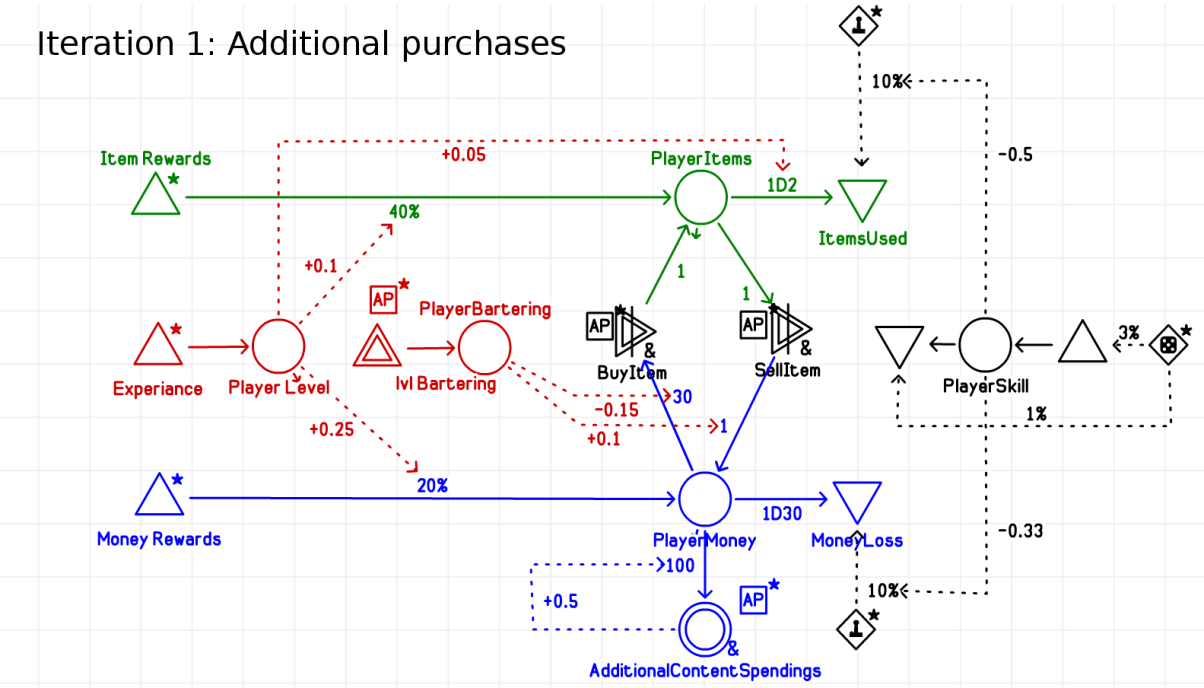

Figure 10

This prototype extends the basic economic system of a game like *The Elder Scrolls V: Skyrim*[64] by adding an additional option to spend high amounts of currency on something that has no further impact on the economic system of the prototype. The price for additional items bought this way will increase the amount of currency the player has to spend to obtain them and the likelihood for the player to buy it will be reduced. This symbolizes that items bought utilizing

[64] (Bethesda Game Studios, The Elder Scrolls V: Skyrim, 2011)

this system will increase in price depending on the amount of currency that must be removed from the game.

ID	Player Level 1	Player Money 1	Player Items 1	Player Level 2	Player Money 2	Player Items 2	Player Level 3	Player Money 3	Player Items 3
MAX	1000	284	98	1000	350	71	1000	266	94
AVERAGE	499.500998	56.05888224	14.25149701	499.500998	71.15269461	13.32634731	499.500998	43.36227545	11.94610778
MEDIAN	499.5	22	6	499.5	22	7	499.5	22	6
MODE	0	0	0	0	0	1	0	3	1

MAX ITEMS	296
AVERAGE ITEMS	21.76958084
MAX MONEY	421
AVERAGE MONEY	54.93874877

Figure 11

If the results of **Figure 11**, which showcases the results of this approach, are compared to the results of **Figure 6**, which showcases the results of the base system, it becomes apparent, that this approach is capable of reducing the maximum amount of currency players own as well as reducing the average amount of currency players own. But the differences between the amounts of currency players own compared to each other doesn't change much. Because of that can this system considered to be unstable. It is also possible, that some players are less affected by this approach than others. Repeating this test for more users will likely result in some users that aren't affected at all, leading to even higher differences between players. More detailed results can be found at https://philippstenger.com/wp-content/uploads/2019/02/Iteration1_ExcelDocumentation.7z.

This approach is only possible for games that are supported over a larger period of time since new items must be added periodically.

7.4.2. Iteration 1: Consumable currency

For this approach the currency of a game is converted in some form of consumable good. An example of this could be food that is necessary because of a nutrition bar that reduces the players' health when empty or a currency that can be directly converted into health. An example of this are the bullets from the *Metro*[65] series. These bullets are utilized as currency but also as ammunition. This approach allows giving a currency a fixed value based on the value the player gets from utilizing it. **Figure 12** shows the prototype for this approach.

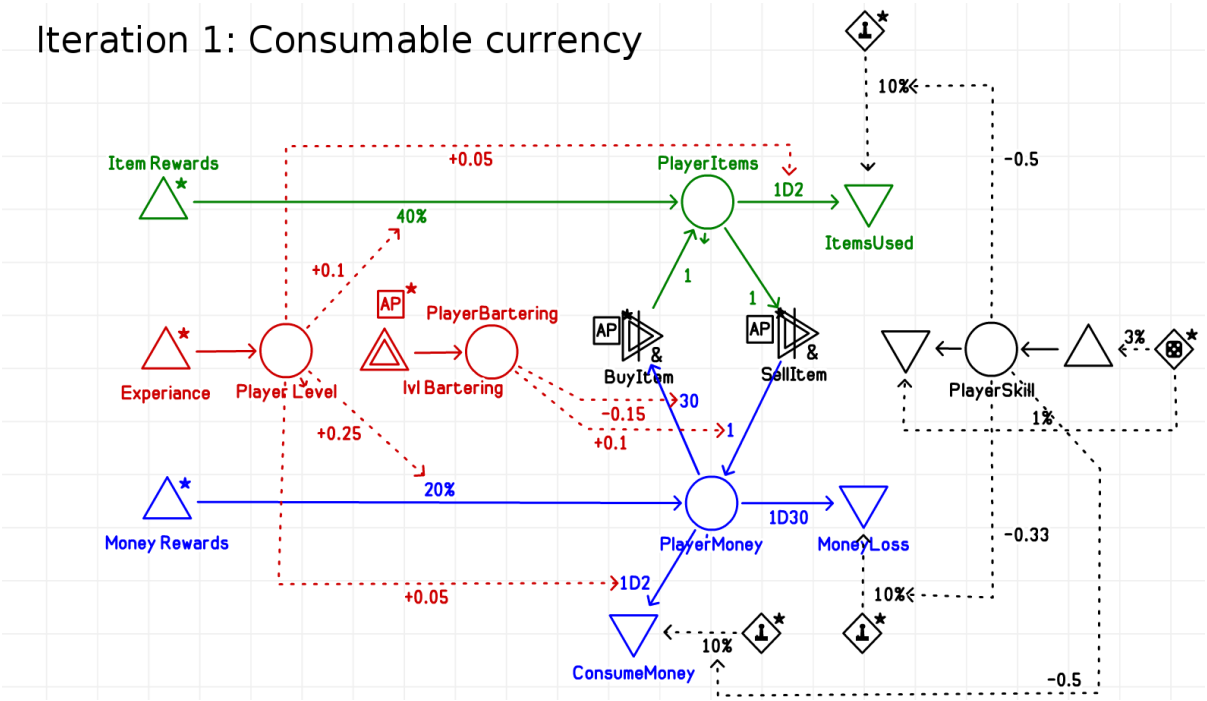

Figure 12

This approach adds an additional currency drain to 'PlayerMoney'. This drain has a random value, but the maximum depends on the progression level of the player and is triggered randomly with a decreasing chance based on the players' skill level. When used for a real game this system can be adjusted by utilizing levels that offer more currency but also have a higher level of difficulty, creating high risk-high reward areas or simply moments that feel very intense.

ID	Player Level 1	Player Money 1	Player Items 1	Player Level 2	Player Money 2	Player Items 2	Player Level 3	Player Money 3	Player Items 3
MAX	1000	115	33	1000	209	70	1000	403	99
MEAN	499.500998	17.61676647	7.065868263	499.500998	23.18063872	11.23353293	499.500998	57.61776447	24.16067864
MEDIAN	499.5	11	5	499.5	13	6	499.5	17	12
VARIANCE S	83749.501	401.6931452	49.27637632	83749.501	1141.283021	177.5518015	83749.501	9186.861742	683.2299008
MODE	0	0	1	0	0	1	0	0	0

MAX ITEMS	310
MEAN ITEMS	21.99052894
MAX MONEY	806
MEAN MONEY	38.76105365

Figure 13

If the results of **Figure 13**, which showcases the results of this approach, are compared to the results of **Figure 6**, which showcases the results of the base system, it becomes apparent, that

[65] (4A Games, 2010)

this approach is capable of reducing the maximum amount of currency players own as well as reducing the average amount of currency players own. But the differences between the amounts of currency players have compared to each other doesn’t change much. Because of that can this system considered to be unstable. This is because players are only inclined to consume currency if the game becomes too difficult. But difficulty depends heavily on the players’ level of skill. More detailed results can be found at https://philippstenger.com/wp-content/uploads/2019/02/Iteration1_ExcelDocumentation.7z.

7.4.3. Iteration 1: Fixed enemy count

In this approach the number of enemies is fixed or limited, this means that enemies won't respawn or only respawn a limited number of times. This limits the amount of currency and items the player can obtain within the game world. Utilizing this approach creates a natural maximum of obtainable goods for each area of the game. This makes it easier to predict how much currency a player has at a certain point of progress. Because of that prices in different areas can be adjusted accordingly. **Figure 14** shows the prototype for this approach.

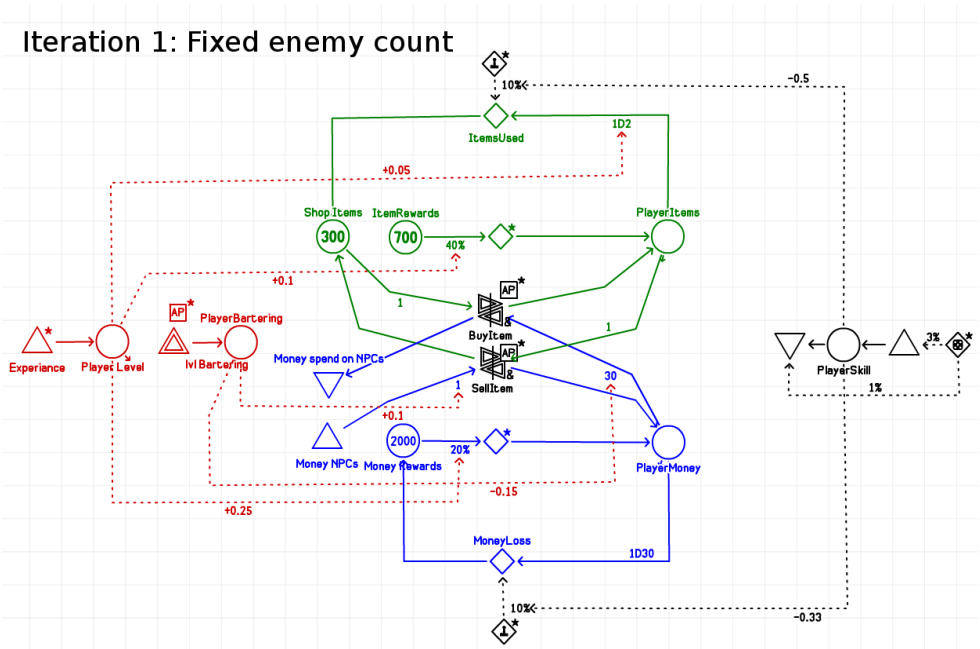

Figure 14

For this approach the infinite sources for currency and items have been replaced with finite pools of money and items. The only infinite source remaining is the currency the NPC-merchants have access to. In addition to that the converters have been replaced with traders to make sure, that currency and items are correctly reallocated to the right pools.

Systems like this prototype can run into the problem that all the currency and items are removed from the game or a certain area in the game. This creates a fail state in which the player can no longer continue playing the game.

ID	Player Level 1	Player Money 1	Player Items 1	Player Level 2	Player Money 2	Player Items 2	Player Level 3	Player Money 3	Player Items 3
MAX	1000	519	36	1000	280	109	1000	258	58
MEAN	499.500998	116.8083832	6.452095808	499.500998	63.82335329	17.20558882	499.500998	65.66966068	7.895209581
MEDIAN	499.5	25	4	499.5	25	6	499.5	26	4
VARIANCE S	83749.501	29952.12908	43.34685375	83749.501	6296.319414	534.4831655	83749.501	4851.062595	110.8771199
MODE	0	0	1	0	0	1	0	0	1

MAX ITEMS	241
MEAN ITEMS	18.36048902
MAX MONEY	1068
MEAN MONEY	68.10339926

Figure 15

Comparing **Figure 15**, the results of this approach, to **Figure 6**, the results of the base system, it becomes apparent, that this approach has no effect on the stability of the economic system at all. It allows for more control about the maximum amount of currency a player can have at a certain point of progression, but has no impact on any amount of currency that is below that

maximum. This in addition to the previously mentioned problem of the creation of a fail state that stops the player from playing the game leads to this approach getting no further iterations. More detailed results can be found at https://philippstenger.com/wp-content/uploads/2019/02/Iteration1_ExcelDocumentation.7z.

Considering this fail state and its limited effectiveness. It becomes safe to assume that this approach should be limited to games that allow the player to restart every time they lose, similar to roguelikes. Because of its limited effect, it is also recommended that this approach should have an additional purpose rather than fixing a games economic structure. Examples for this could be: Incentivising the player to move to new areas or allowing the player to remember previous events when returning to an area.

7.4.4. Iteration 1: Fixed valuables count

For this approach all valuables the game has are fixed. This means that all NPC-merchants have a fixed amount of currency and items. All crates, chests, herbs, etc. found within the game world can only be looted once and enemies won't respawn or at least won't drop additional loot after being killed once. This is, unless they take the loot from a fixed pool that can only refill when the player consumes items. Because of this the maximum amount of currency is fixed and the game economy becomes more predictable for the same reasons mentioned in 'Iteration 1: Fixed enemy count'. **Figure 16** shows the prototype for this approach.

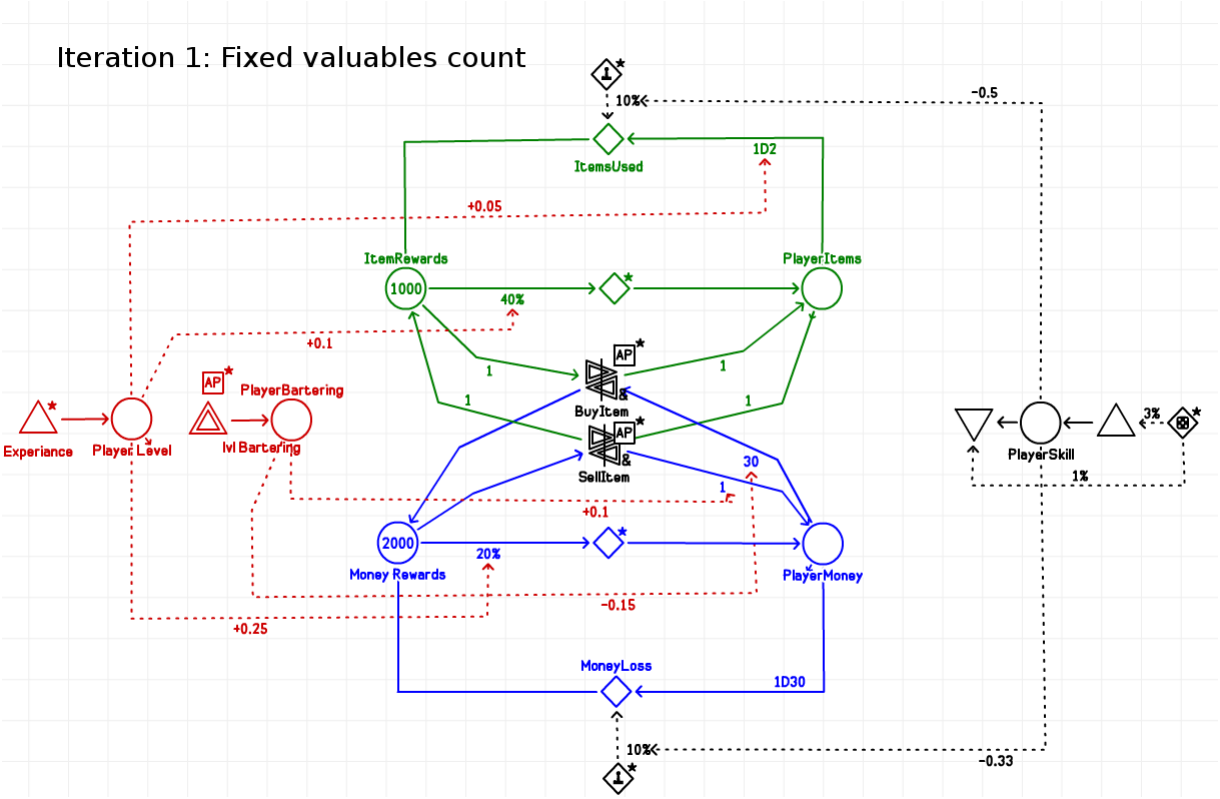

Figure 16

For this approach all infinite sources for currency and items have been replaced with finite pools of money and items. In addition to that the converters have been replaced with traders to make sure, that currency and items are correctly reallocated to the right pools.

Similar to the prototype in 'Iteration 1: Fixed enemy count' can this system run into the problem that all the currency and items are removed from the game or a certain area in the game, which creates a fail state in which the player can no longer continue to play.

ID	Player Level 1	Player Money 1	Player Items 1	Player Level 2	Player Money 2	Player Items 2	Player Level 3	Player Money 3	Player Items 3
MAX	1000	230	100	1000	385	88	1000	394	109
MEAN	499.500998	39.21656687	23.58882236	499.500998	47.66766467	19.83233533	499.500998	62.51097804	17.99800399
MEDIAN	499.5	22	10	499.5	24	11	499.5	26	8
VARIANCE S	83749.501	2171.738267	687.2493455	83749.501	4718.765567	449.1486837	83749.501	6263.073306	521.024971
MODE	0	0	1	0	21	1	0	0	1

MAX ITEMS	287
MEAN ITEMS	22.76257485
MAX MONEY	1108
MEAN MONEY	78.09824795

Figure 17

Similar to ‘Iteration 1: Fixed enemy count’ Comparing **Figure 17**, the results of this approach, to **Figure 6**, the results of the base system, shows that this approach has no effect on the stability of the economic system at all. It allows for more control about the maximum amount of currency a player can own at a certain point of progression, but has no effect below that maximum. This in addition to the previously mentioned problem of the creation of a fail state that stops the player from playing the game leads to this approach getting no further iterations. More detailed results can be found at https://philippstenger.com/wp-content/uploads/2019/02/Iteration1_ExcelDocumentation.7z.

Similar to ‘Iteration 1: Fixed enemy count’ if one considers the fail state and the limited effectiveness this approach, it becomes clear that it should be limited to games that allow the player to restart every time they lose. Because of its limited effect, it is also recommended that this approach should have an additional purpose rather than fixing a games economic structure. Examples for this could be: Incentivising the player to move to new areas or allowing the player to remember previous events when returning to an area.

7.4.5. Iteration 1: Scaling costs

In this approach the costs the player can expect during the game scale with the amount of currency the player owns. Because of this gaining more currency becomes harder depending on the amount of currency the player already owns. This creates a negative feedback loop[66] for obtaining currency for any specific value the economic system is balanced for. **Figure 18** shows the prototype for this approach.

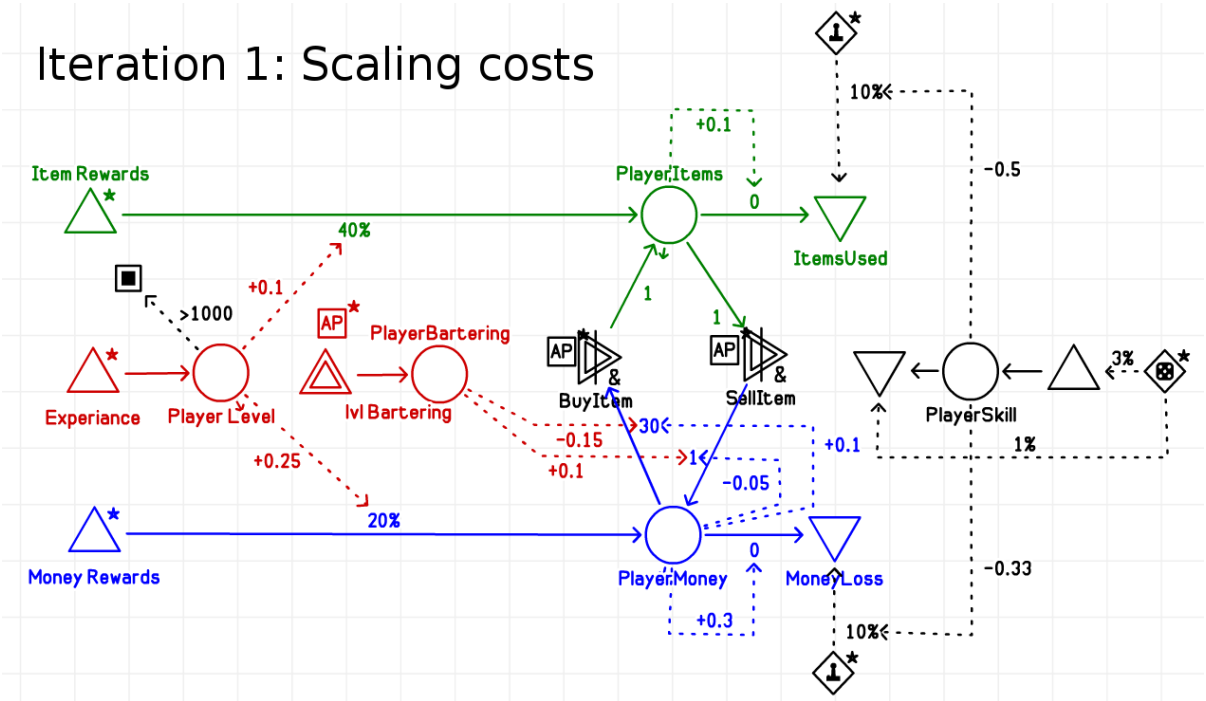

Figure 18

In this prototype the amount of currency the player loses from random events in 'MoneyLoss' and the amount of currency the player obtains or loses from selling and buying in 'BuyItem' and 'SellItem' items scales negatively with the current amount of currency the player owns.

ID	Player Level 1	Player Money 1	Player Items 1	Player Level 2	Player Money 2	Player Items 2	Player Level 3	Player Money 3	Player Items 3
MAX	996	189	253	996	161	205	996	113	222
MEAN	495.5149701	36.20558882	120.3832335	495.5149701	25.11177645	79.57884232	495.5149701	22.52694611	82.94211577
MEDIAN	495.5	24	124.5	495.5	21	57	495.5	20	68.5
VARIANCE S	83735.59468	1288.670978	7466.344494	83735.59468	414.1293517	4487.526745	83735.59468	287.7759965	4354.386256
MODE	0	0	0	0	0	0	0	0	0

MAX ITEMS	319
MEAN ITEMS	78.36503992
MAX MONEY	211
MEAN MONEY	26.84199278

Figure 19

Comparing the values from **Figure 19** to **Figure 6** it becomes apparent that this approach effectively increases the stability of the economic system of the game, since the different values for the currency don't fluctuate much between the different playthroughs and the max amount of currency is limited to a more stable amount. More detailed results can be found at https://philippstenger.com/wp-content/uploads/2019/02/Iteration1_ExcelDocumentation.7z.

[66] (Salen & Zimmerman, 2004, p. Chapter 18)

This approach is a good start for the creation of a stable economic system, but is likely that it has a more mental limitation. This is because of the expectation that players will not enjoy the basic concept of this approach since directly increasing prices based on the amount of currency a player owns can feel very unfair or undesirable. But this approach can also be achieved in another way. For example, players that have a lot of currency will be attacked by bandits more often. Now even if a player manages to defeat the bandits every time without losing the owned currency, it is likely, those extra consumables are used during the fights, which effectively removes valuables from the player. Another way to properly include this approach into a game would be by utilizing taxes or upkeep costs that scale with a players’ possessions.

7.4.6. Iteration 1: Stop scaling gains

In this approach the increasing amount of valuables the player is able to obtain is limited at a certain point. This caps the amount of income a player can generate. **Figure 20** shows the prototype for this approach.

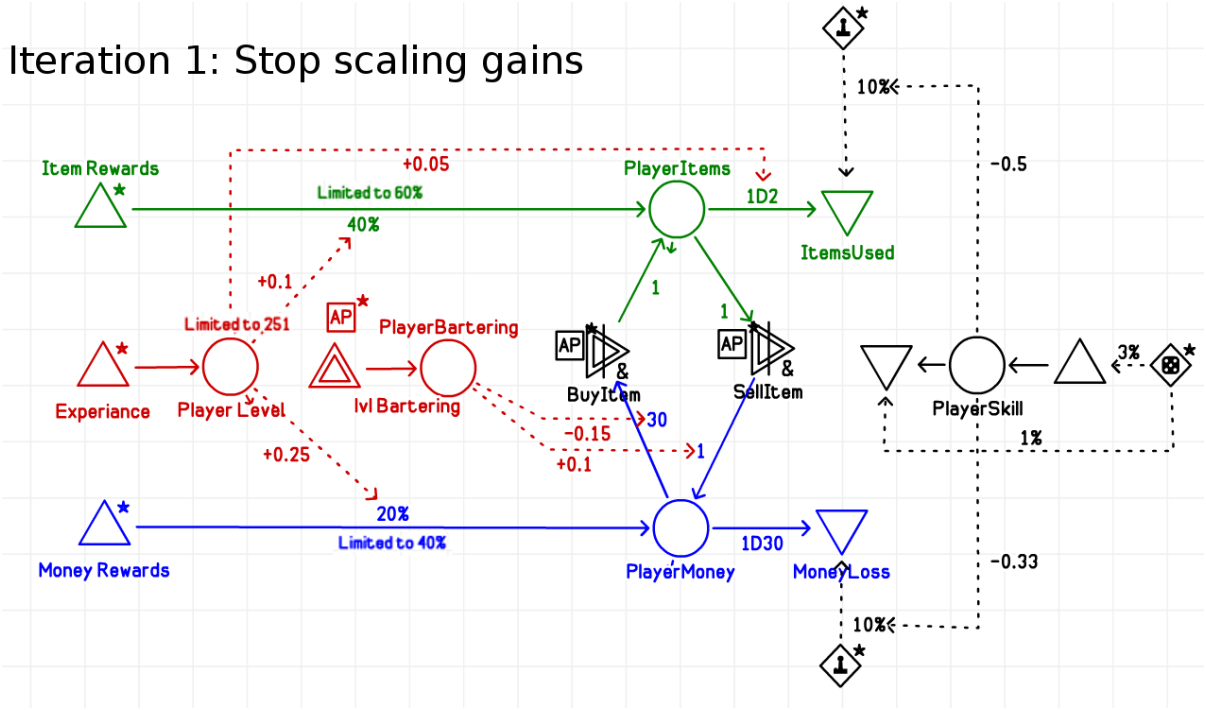

Figure 20

In this prototype the maximum amount of 'ItemRewards' income is capped to 60%, the maximum amount of 'MoneyRewards' is caped to 40% and the maximum 'Player Level' is caped to 251. This reduces the maximum income a player can generate.

In a game this effect could be achieved by for example: Keeping the amount of value in loot on enemies the same over multiple levels, which can be achieved by reducing the value of loot on most enemies and allow a small percentage to drop very valuable items.

ID	Player Level 1	Player Money	Player Items 1	Player Level 2	Player Money	Player Items 2	Player Level 3	Player Money	Player Items 3
MAX	251	114	75	251	77	35	251	134	33
MEAN	218.1846307	26.92814371	16.30239521	218.1846307	18.70159681	5.637724551	218.1846307	29.16566866	6.862275449
MEDIAN	251	18	7	251	16	4	251	18	4
VARIANCE S	4534.094749	656.0108155	406.3829913	4534.094749	229.5841933	36.80668732	4534.094749	896.0504486	50.85014387
MODE	251	0	0	251	0	0	251	0	1

MAX ITEMS	188
MEAN ITEMS	15.01291417
MAX MONEY	551
MEAN MONEY	30.56394282

Figure 21

Comparing the values from **Figure 21** to **Figure 6** it becomes apparent that this approach effectively reduces the overall fluctuation between currency values, but comes with the disadvantage that it features several playthroughs with extreme cases. More detailed results can be found at https://philippstenger.com/wp-content/uploads/2019/02/Iteration1_ExcelDocumentation.7z.

This approach shows great theoretical potential, since it should be possible to stop the scaling of gains within specific progression levels, allowing the designer to create a stable system that fits to the offers of NPC-merchants for certain areas of the game. But the problem of this system is, that it is hard to predict at which point the scaling of the economic system of the game should stop to create interesting prices for the NPC-merchants’ offers at the players’ progression level. Because of this not automatically adjusting nature of this approach further development is necessary. But it should be mentioned, that this approach is a great addition to other approaches for the creation of a stable economic system and will be utilized in this way in upcoming prototypes.

7.4.7. Iteration 2: Additional purchases with a higher chance based on game progression

In this iteration the chance that the player purchases the additionally added items increases over the progression of the game. This has the intention to make this approach more reliable. **Figure 22** shows the prototype for this approach.

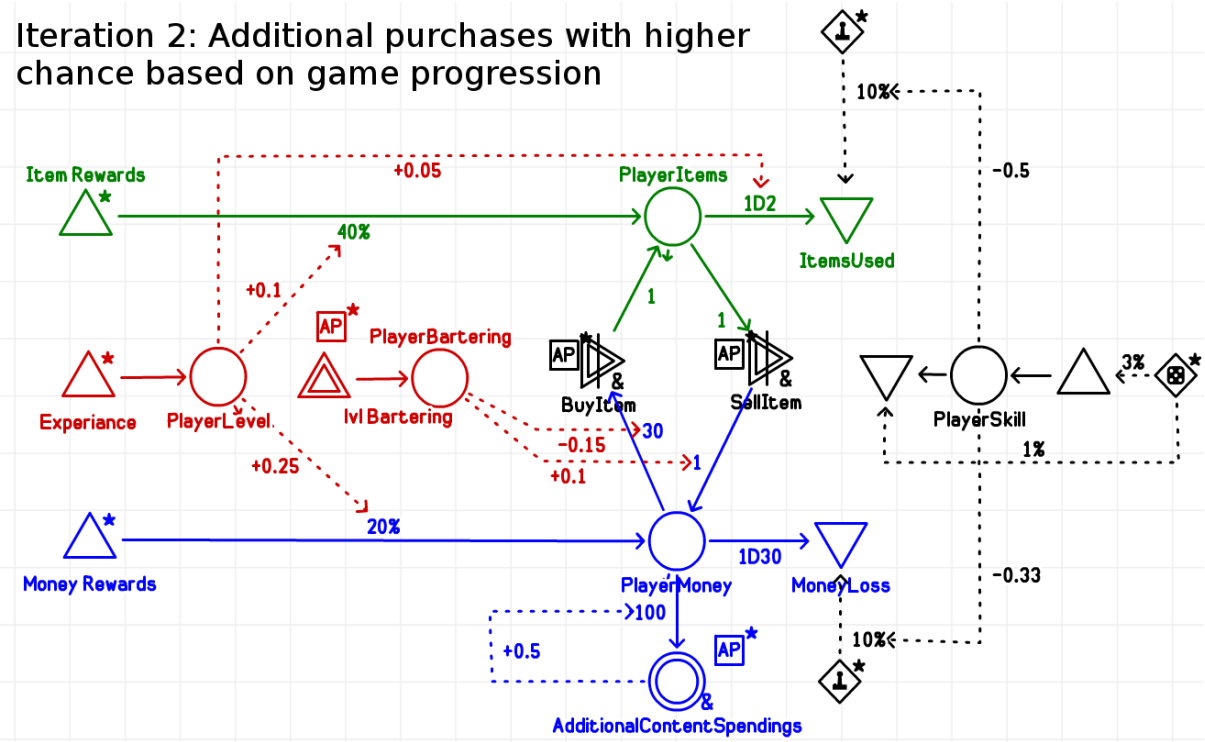

Figure 22

For this iteration, the 'ArtificialPlayer' has been altered in a way that increases the progression level also increases the chance that 'AdditionalContentSpendings' will be triggered. Since the system that makes it less likely that 'AdditionalContentSpendings' will be triggered depending on how much currency the player has already spent on it and more likely that 'AdditionalContentSpendings' will be triggered depending on how much currency the player has still exists, is this just an additional element to allow to balance how often a player spends currency on additional items.

In a real game, the likelihood of a player spending currency on additional items could be increased by adding more options for the player to choose from. But different players have different preferences which makes it difficult to predict what is necessary to increase the chance for a player to purchase any of the additional items.

ID	Player Level 1	Player Money 1	Player Items 1	Player Level 2	Player Money 2	Player Items 2	Player Level 3	Player Money 3	Player Items 3
MAX	1000	318	75	1000	323	62	1000	246	145
MEAN	499.500998	66.76047904	12.75349301	499.500998	59.82335329	14.0499002	499.500998	40.44710579	20.65269461
MEDIAN	499.5	26	8	499.5	27	10	499.5	20	8
VARIANCE S	83749.501	5436.162353	207.380732	83749.501	5298.095638	189.8916134	83749.501	2639.170526	862.1729648
MODE	0	11	1	0	0	1	0	2	0

MAX ITEMS	283
MEAN ITEMS	19.79122754
MAX MONEY	437
MEAN MONEY	53.12558721

Figure 23

Comparing the values of **Figure 23** to **Figure 11** shows that this iteration has no large scale effect compared to the first iteration. However, it should be noted that the total amount of extreme cases has been reduced. Because of the difficulty to determine how the chances for a player to purchase any additional items can be increased and the miniscule effectiveness of this iteration will this approach not receive any additional iterations. More detailed results can be found at https://philippstenger.com/wp-content/uploads/2019/02/Iteration2_ExcelDocumentation.7z.

The use cases for this iteration are the same as the use cases of the first iteration.

7.4.8. Iteration 2: Consumable currency with scaling difficulty based on currency amount

For this iteration the difficulty of the game changes based on the amount of currency the player has access to. This works well in combination with consumable currency, since the player is able to use it if the game gets too hard to overcome the challenge, which then reduces the amount of currency the player has and with that the difficulty of the next encounters. This system can easily be explained to the player in the ways mentioned in 'Iteration 1: Scaling costs'. This iteration has the intention to make this approach more reliable. **Figure 24** shows the prototype for this approach.

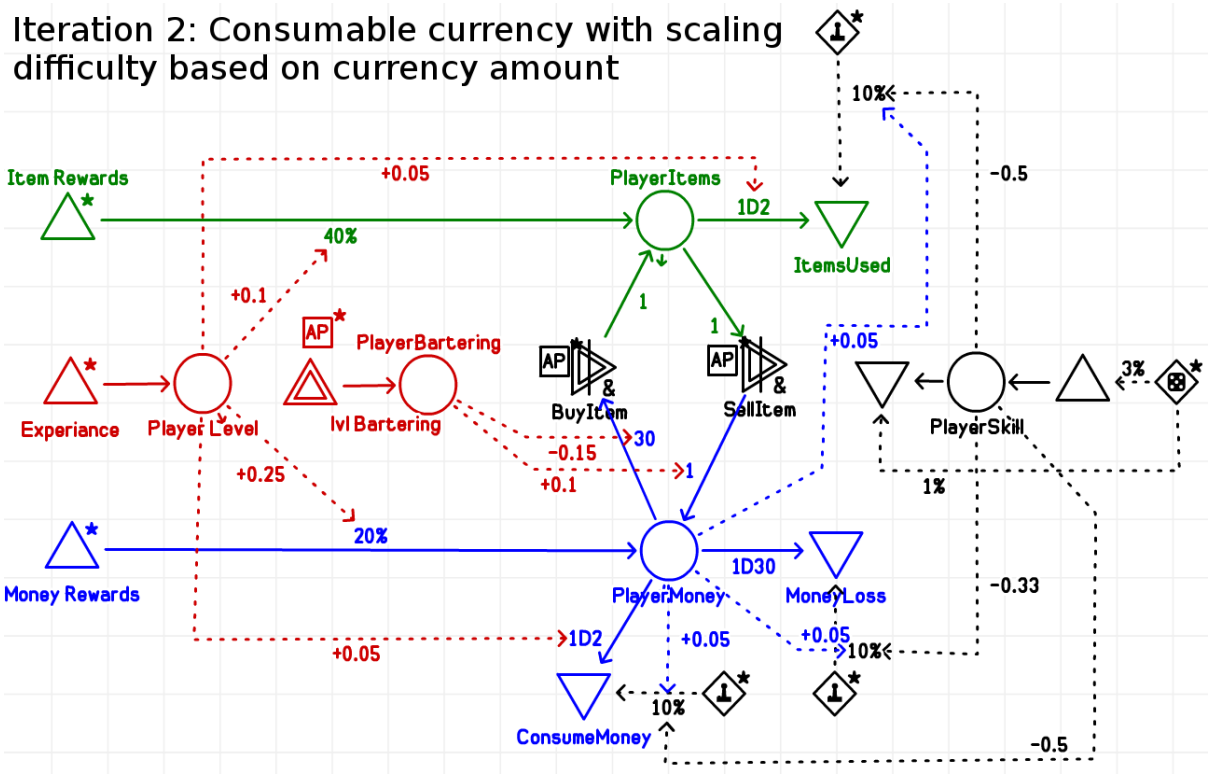

Figure 24

In this iteration the chance for the player to trigger 'ConsumeMoney' is increased based on the amount of currency in 'PlayerMoney'.

ID	Player Level 1	Player Money 1	Player Items 1	Player Level 2	Player Money 2	Player Items 2	Player Level 3	Player Money 3	Player Items 3
MAX	1000	180	63	1000	172	111	1000	210	103
MEAN	499.500998	28.7994012	8.180638723	499.500998	17.80439122	15.61277445	499.500998	21.09081836	22.54391218
MEDIAN	499.5	16	4	499.5	11	5	499.5	14	11
VARIANCE S	83749.501	1141.053626	104.4198845	83749.501	588.1974632	624.3913651	83749.501	758.8458896	662.8796882
MODE	0	0	1	0	0	0	0	0	1

MAX ITEMS	234
MEAN ITEMS	16.67247505
MAX MONEY	279
MEAN MONEY	23.81889756

Figure 25

Comparing the values of **Figure 25** to **Figure 13** shows that the average between the players that have stable amounts of currencies has not changed much. But the strength and amount of extreme cases are reduced by a large number. This comes from the now introduced negative

feedback loop[67] for the amount of currency a player has access to. As an added bonus is this approach capable of automatically adjusting its difficulty depending on the amount of currency the players are forced to use. This passively increases the difficulty of the game for skilled players. More detailed results can be found at https://philippstenger.com/wp-content/uploads/2019/02/Iteration2_ExcelDocumentation.7z.

The use cases for this iteration are the same as the first iteration with the limitation that the game must be able to increase its difficulty curve adaptively.

[67] (Salen & Zimmerman, 2004, p. Chapter 18)

7.4.9. Iteration 2: Scaling costs and reverse scaling gains

For this iteration an additional scaling that allows the player to receive more currency if the total amount of currency is low has been added to the prototype. The objective for this is to create a double negative feedback loop[68] for having too much or too little currency. This has the goal of giving the player access to a specific amount of currency most of the time. **Figure 26** shows the prototype for this approach.

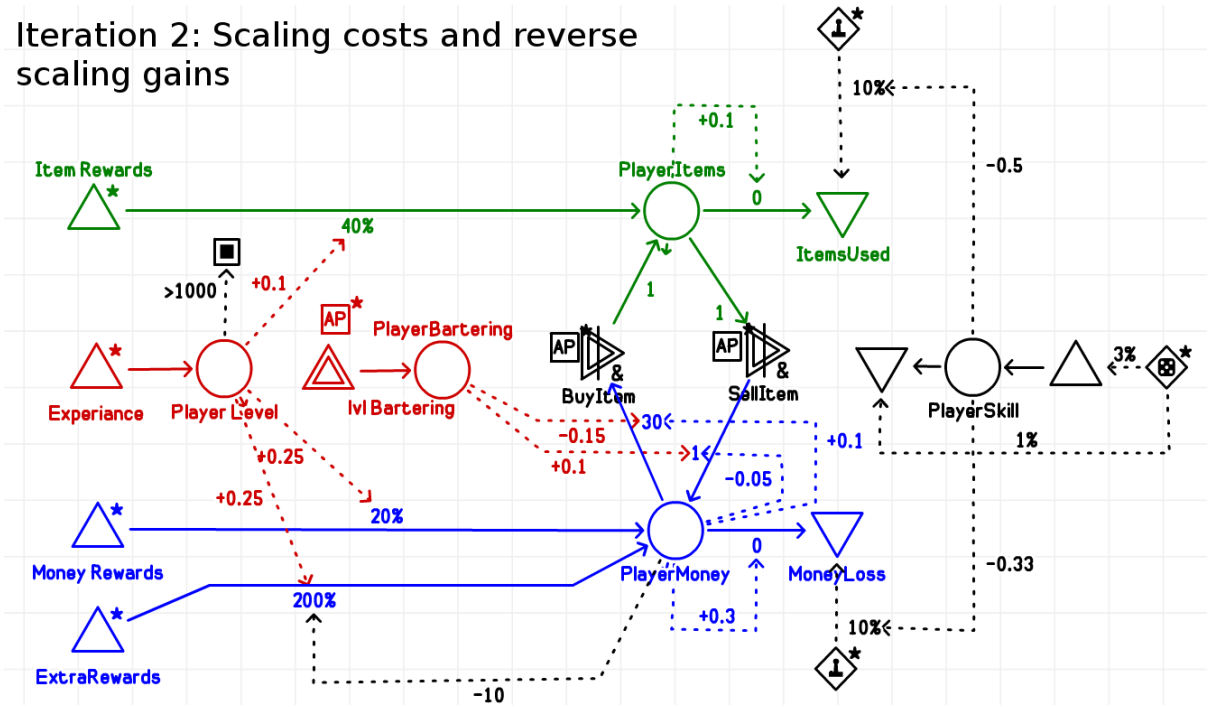

Figure 26

An additional way of obtaining income has been created in the form of 'ExtraRewards' the income created from this source is reduced dependence on the amount of currency the player has in 'PlayerMoney'.

In a game, this form of income is hard to explain without removing the power fantasy from the player, but maybe that is exactly what it could be used for to create a stronger contrast for success and failure in games.

ID	Player Level 1	Player Money 1	Player Items 1	Player Level 2	Player Money 2	Player Items 2	Player Level 3	Player Money 3	Player Items 3
MAX	1000	103	265	1000	125	251	1000	121	172
MEAN	499.500998	30.61976048	77.76546906	499.500998	30.48003992	89.72754491	499.500998	33.9510978	63.80139721
MEDIAN	499.5	27	44	499.5	27	76	499.5	30	62
VARIANCE S	83749.501	330.0760527	5482.39549	83749.501	372.0600408	5273.696923	83749.501	442.2083954	2374.764713
MODE	0	21	12	0	21	8	0	27	14

MAX ITEMS	430
MEAN ITEMS	99.22225549
MAX MONEY	200
MEAN MONEY	33.39757858

Figure 27

Comparing the values of **Figure 27** with **Figure 19**, it becomes apparent that the overall stability increase of this iteration compared to the first iteration is fairly similar, but the differences between the playthroughs have been reduced to stable values. This makes this a promising

[68] (Salen & Zimmerman, 2004, p. Chapter 18)

approach for the creation of a stable economic system for games. More detailed results can be found at https://philippstenger.com/wp-content/uploads/2019/02/Iteration2_ExcelDocumentation.7z.

The use cases for this iteration are the same as the first iteration, but with the added limitation that it is also necessary to explain that having less currency leads to gaining more currency. If the game is able to properly do so this system should be a good fit to create a stable economic system.

7.4.10. Iteration 2: Scaling costs and stop scaling gains

For this iteration the approaches scaling cost and stop scaling gains have been combined, to create a stable economic system that can be adjusted to specific levels of progression. This iteration has the goal of creating a more stable economic system in the way 'Iteration 1: Scaling costs' has already demonstrated, while also reducing the amount and strengths of extreme cases by limiting the amount of income the player can generate at specific levels of progression. **Figure 28** shows the prototype for this approach.

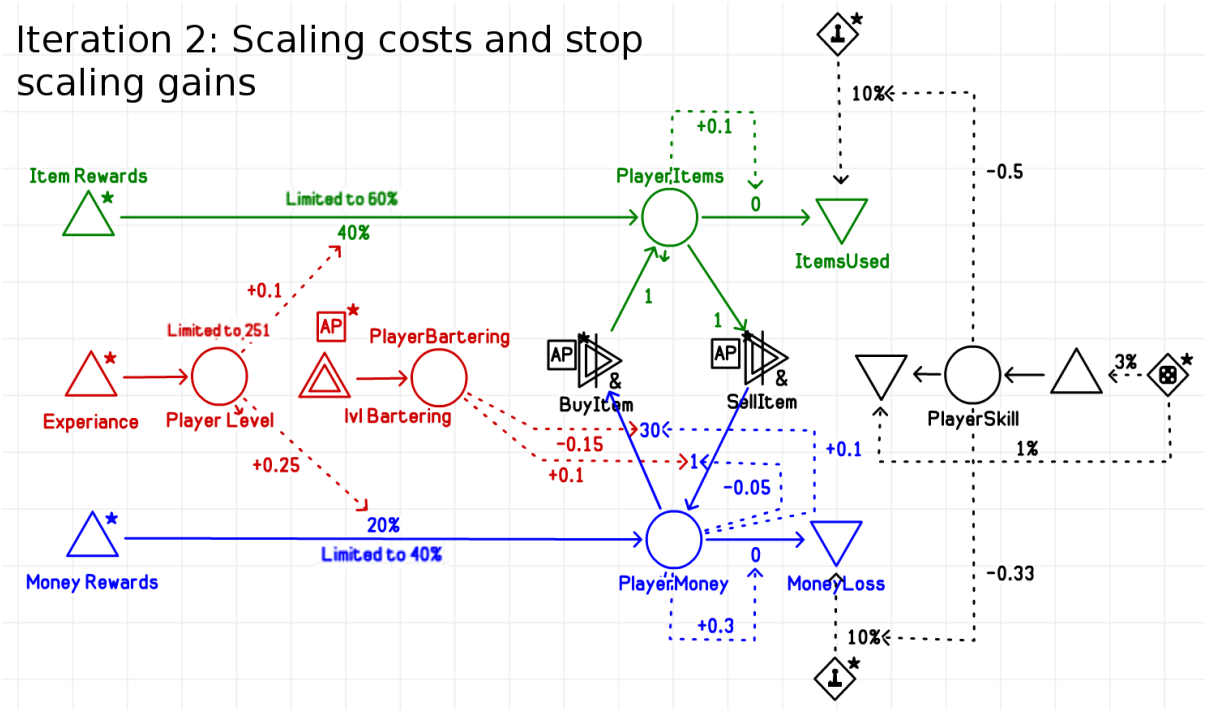

Figure 28

For this iteration all changes of 'Iteration 1: Scaling costs' and 'Iteration 1: Stop scaling gains' have been combined.

ID	Player Level 1	Player Money 1	Player Items 1	Player Level 2	Player Money 2	Player Items 2	Player Level 3	Player Money 3	Player Items 3
MAX	1000	114	276	1000	138	285	1000	74	287
MEAN	499.500998	29.63473054	106.0548902	499.500998	26.37924152	105.0578842	499.500998	22.08483034	96.87025948
MEDIAN	499.5	23	82	499.5	20.5	84	499.5	20	83
VARIANCE S	83749.501	469.6206907	6785.816165	83749.501	554.2736146	7364.12252	83749.501	171.4962931	6651.669464
MODE	0	15	0	0	19	26	0	11	1

MAX ITEMS	395
MEAN ITEMS	97.21541916
MAX MONEY	177
MEAN MONEY	28.35063207

Figure 29

Comparing **Figure 29** to **Figure 19** and **Figure 21** it becomes clear that this iteration is success full in reaching its goal of combining the stability increase from 'Iteration 1: Scaling costs' with the reduction of extreme cases from 'Iteration 1: Stop scaling gains'. Since this confirms the effect that 'Iteration 1: Stop scaling gains' has on other approaches, will this system not receive any further iterations but rather be combined with other approaches. More detailed results can be found at https://philippstenger.com/wp-content/uploads/2019/02/Iteration2_ExcelDocumentation.7z.

This iteration is limited to games that can support ‘Iteration 1: Scaling costs’ and ‘Iteration 1: Stop scaling gains’. It also showcases that ‘Iteration 1: Stop scaling gains’ can be utilized for any game that supports its implementation to reduce the number of extreme cases. In addition to that it appears, that ‘Iteration 1: Stop scaling gains’ is heavily improved when combined with another way that stabilizes the games’ economy based on its current amount of destabilization. This is likely because it is almost impossible to guarantee that all forms of gains are accounted for or balanced correctly.

7.4.11. Iteration 3: Consumable currency with scaling difficulty based on currency amount while also reducing the difficulty under a certain amount of currency

In this iteration 'Iteration 2: Consumable currency with scaling difficulty based on currency amount' gets further developed by also reducing the difficulty of the game while the player owns less than a certain amount of currency. This has the goal of allowing the player to get to a certain amount of currency safely and by doing so concentrating the usual amount of currency owned by the player to a specific amount. In addition to this the strength of the effect that pushes a player to consume currency is increased. This has the goal of reducing fluctuations between the average amounts of currency a player has access to across multiple playtroughs. **Figure 30** shows the prototype for this approach.

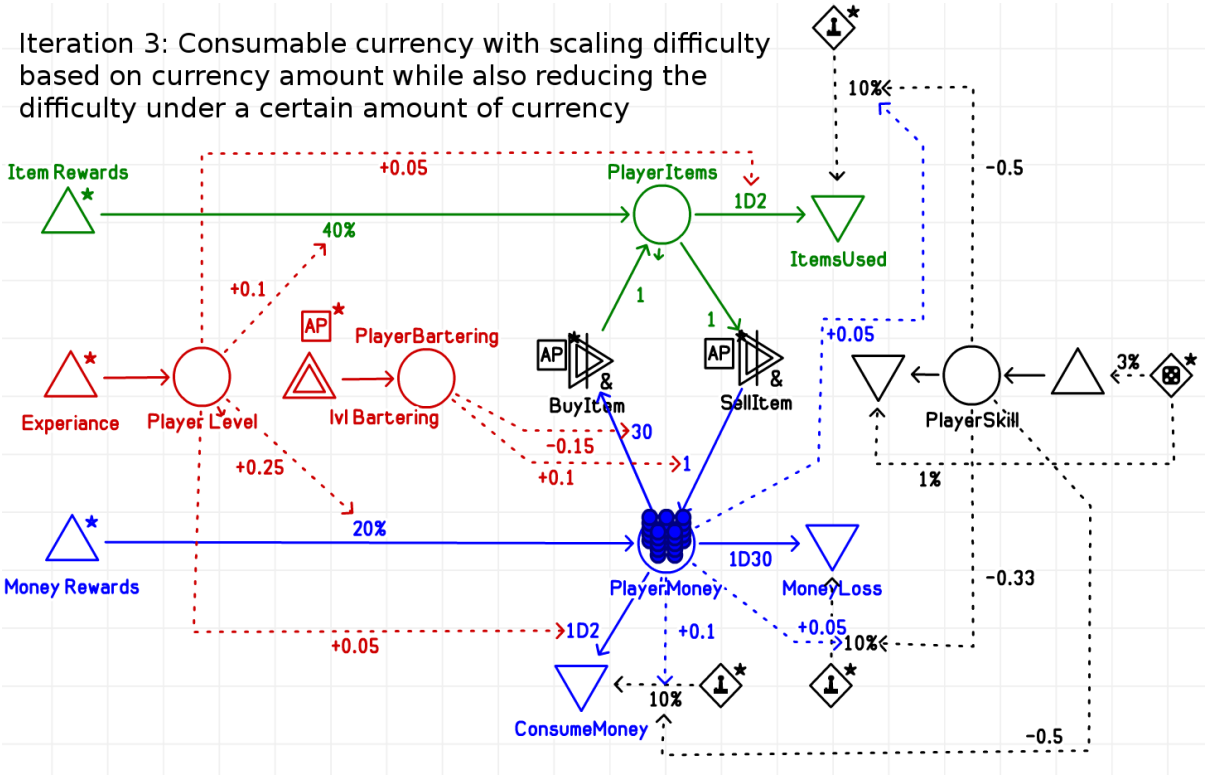

Figure 30

For this iteration the player has access to an amount of starting currency in 'PlayerMoney' and all implementations of difficulty scaling depending on currency work in reverse if the player has less than the amount of starting currency. In addition to that the strength with which 'PlayerMoney' effects 'ConsumeMoney' has been increased to better understand the strength that this handle gives to the designer.

ID	Player Level 1	Player Money	Player Items 1	Player Level 2	Player Money	Player Items 2	Player Level 3	Player Money	Player Items 3
MAX	1000	133	121	1000	119	81	1000	175	175
MEAN	499.500998	25.23253493	14.81636727	499.500998	25.32135729	15.11676647	499.500998	32.70658683	29.19161677
MEDIAN	499.5	19	7	499.5	18	8	499.5	23	8
VARIANCE S	83749.501	551.417402	466.2679436	83749.501	588.7817412	287.042296	83749.501	1120.982754	1887.55965
MODE	0	3	1	0	0	2	0	0	1

MAX ITEMS	268
MEAN ITEMS	19.0644012
MAX MONEY	215
MEAN MONEY	25.34515817

Figure 31

Comparing the values of **Figure 31** to **Figure 25** shows that this approach has increased the average amount of currency a player owns while also reducing the maximum amount of currency a player owns. Indicating that increasing and reducing the difficulty based on the amount of currency a player owns, in an economic system that utilizes this approach, does allow to control the average amount of currency on a player towards a specific value. This iteration also proves that increasing the effectiveness of the scaling does little to temper with the averages but heavily effects the maximum values. More detailed results can be found at https://philippstenger.com/wp-content/uploads/2019/02/Iteration3_ExcelDocumentation.7z.

The use cases of this approach haven’t changed from ‘Iteration 2: Consumable currency with scaling difficulty based on currency amount’.

7.4.12. Iteration 3: Scaling costs and reverse scaling gains while also stopping the scaling of gains on a specific level of progression

In this iteration 'Iteration 2: Scaling costs and reverse scaling gains' is combined with 'Iteration 1: Stop scaling gains', to create a stable economic system that can be adjusted to specific levels of progression. This iteration has the goal of creating a more stable economic system in the way 'Iteration 2: Scaling costs and reverse scaling gains' has already demonstrated, while also reducing the amount and strengths of extreme cases by limiting the amount of income the player can generate at specific levels of progression. In **Figure 32** the prototype for this approach can be seen.

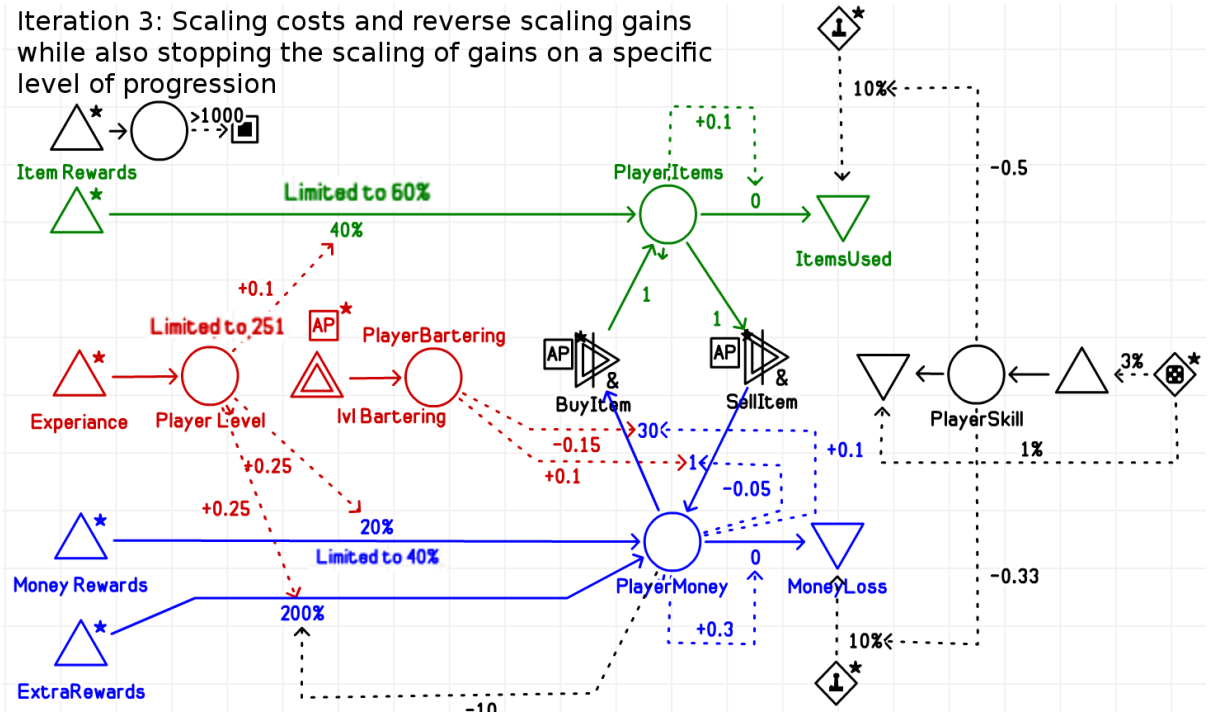

Figure 32

For this iteration all changes of 'Iteration 2: Scaling costs and reverse scaling gains' and 'Iteration 1: Stop scaling gains' have been combined.

ID	Player Level 1	Player Money 1	Player Items 1	Player Level 2	Player Money 2	Player Items 2	Player Level 3	Player Money 3	Player Items 3
MAX	251	147	126	251	91	108	251	127	132
MEAN	218.1846307	28.19161677	54.18662675	218.1846307	25.28043912	41.35628743	218.1846307	27.45608782	65.80838323
MEDIAN	251	23	53	251	23	36	251	22	65.5
VARIANCE S	4534.094749	518.0651444	1327.152948	4534.094749	278.0461505	782.8030024	4534.094749	506.7558121	2037.371838
MODE	251	0	0	251	0	0	251	0	0

MAX ITEMS	197
MEAN ITEMS	57.22505988
MAX MONEY	151
MEAN MONEY	25.75801931

Figure 33

Comparing **Figure 33** to **Figure 27** and **Figure 21** it becomes clear that this iteration is success full in reaching its goal of combining the stability increase from 'Iteration 2: Scaling costs and reverse scaling gains' with the reduction of extreme cases from 'Iteration 1: Stop scaling gains'. More detailed results can be found at https://philippstenger.com/wp-content/uploads/2019/02/Iteration3_ExcelDocumentation.7z.

This iteration is limited to games that can support ‘Iteration 2: Scaling costs and reverse scaling gains’ and ‘Iteration 1: Stop scaling gains’.

7.4.13. Iteration 4: Consumable currency with scaling difficulty based on currency amount while also reducing the difficulty under a certain amount of currency and stop scaling currency

For this approach 'Iteration 3: Consumable currency with scaling difficulty based on currency amount while also reducing the difficulty under a certain amount of currency' and 'Iteration 1: Stop scaling gains' have been combined, with the goal of combining the stability increase of 'Iteration 3: Consumable currency with scaling difficulty based on currency amount while also reducing the difficulty under a certain amount of currency' with the capability of reducing the amount and strength of extreme cases 'Iteration 1: Stop scaling gains' offers. **Figure 34** shows the prototype for this approach.

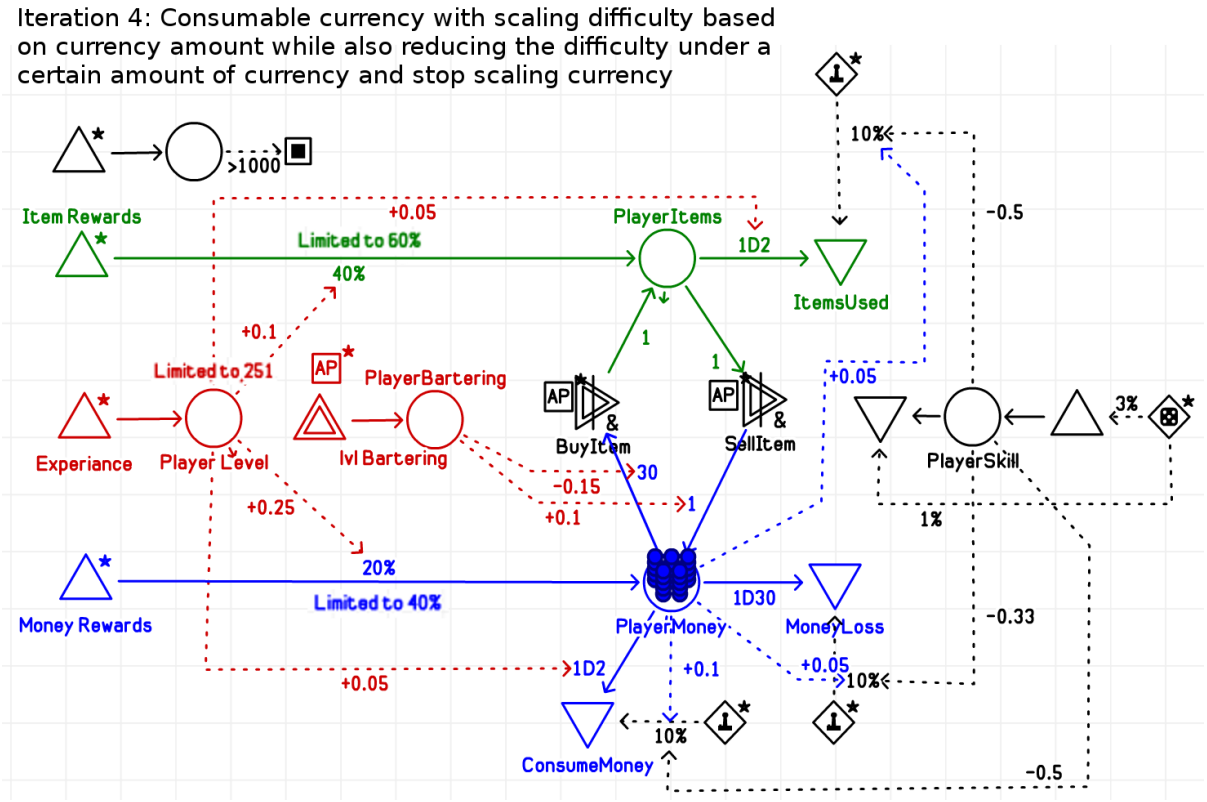

Figure 34

For this iteration all changes of 'Iteration 3: Consumable currency with scaling difficulty based on currency amount while also reducing the difficulty under a certain amount of currency' and 'Iteration 1: Stop scaling gains' have been combined.

ID	Player Level 1	Player Money 1	Player Items 1	Player Level 2	Player Money 2	Player Items 2	Player Level 3	Player Money 3	Player Items 3
MAX	251	124	38	251	76	72	251	144	41
MEAN	219.1866267	15.91716567	7.366267465	219.1866267	17.57085828	12.27944112	219.1866267	18.83033932	9.575848303
MEDIAN	251	12	5	251	14	6	251	12	5
VARIANCE S	4347.164936	294.5236011	58.98759225	4347.164936	211.8915775	272.0557008	4347.164936	496.3967609	102.9457897
MODE	251	1	0	251	5	1	251	0	2

MAX ITEMS	133
MEAN ITEMS	13.40577844
MAX MONEY	212
MEAN MONEY	21.98878002

Figure 35

Comparing **Figure 35** to **Figure 31** the main difference is that the overall amount of currency and items got scaled down, but the number and strength of extreme cases have not changed much. The reason for this could be that ‘Iteration 3: Consumable currency with scaling difficulty based on currency amount while also reducing the difficulty under a certain amount of currency’ did already handle extreme cases well. The overall result for this approach is that it works well for keeping the maximum and average amount of currency and items the player has access to within a specific area, while offering enough handles to the designer to properly define that area. But within that area the maximum and average amount of currency and items can fluctuate heavily between different players. More detailed results can be found at https://philippstenger.com/wp-content/uploads/2019/02/Iteration4_ExcelDocumentation.7z.

Since how much this approach influences the amount of currency and items the player gets and needs during a playthrough can be controlled very precisely by increasing and reducing the effects of the negative feedback for having low and high amounts of currency and items, should this approach work for any game that fits the requirements of ‘Iteration 3: Consumable currency with scaling difficulty based on currency amount while also reducing the difficulty under a certain amount of currency’ and ‘Iteration 1: Stop scaling gains’. That being said it is recommended that this approach is utilized for games that allow the player to remain effective independent of the skill level. This approach is best used for the creation of economic boundaries in which the player can operate freely.

7.4.14. Iteration 4: Scaling costs and reverse scaling gains while also stopping the scaling of gains on a specific level of progression with extension to items

This iteration extends on 'Iteration 3: Scaling costs and reverse scaling gains while also stopping the scaling of gains on a specific level of progression' by also adding a negative scaling to low amounts of items. This has the goal of further refining the already functional 'Iteration 3: Scaling costs and reverse scaling gains while also stopping the scaling of gains on a specific level of progression' by reducing problems with the trading system. In **Figure 36** the prototype for this approach can be seen.

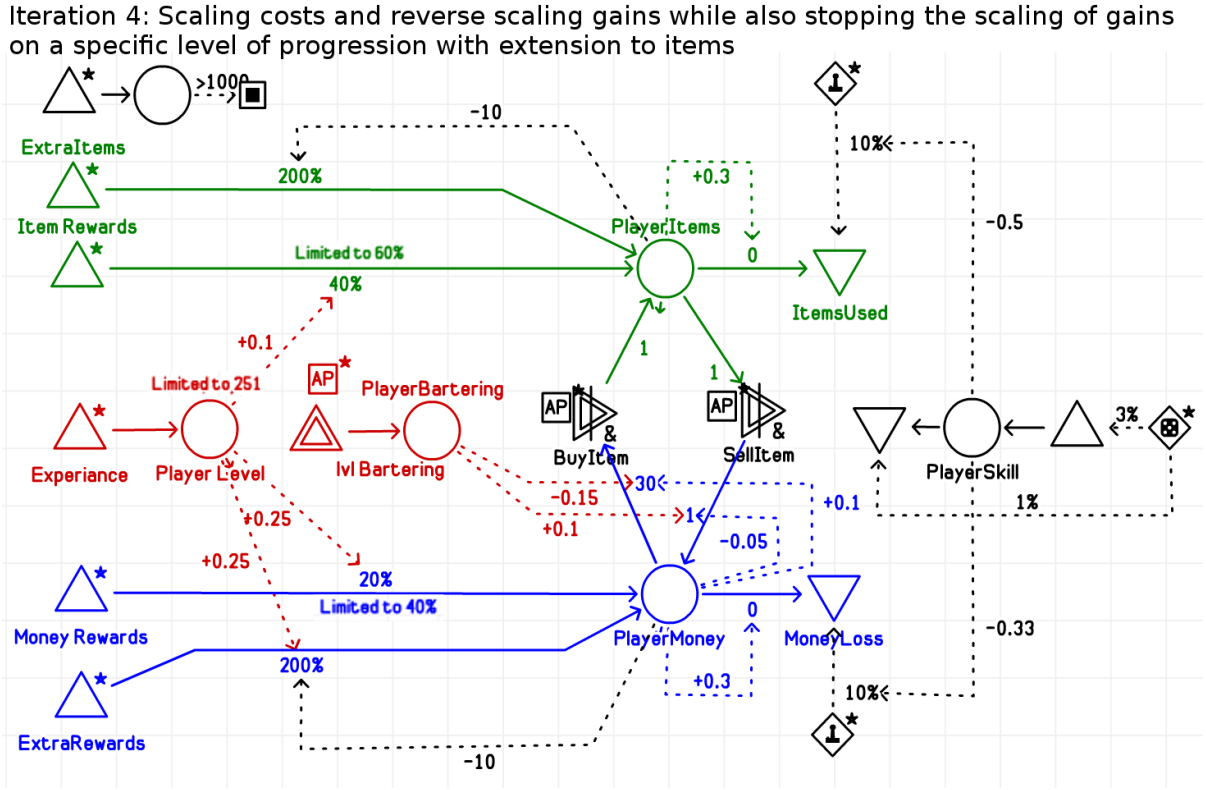

Figure 36

For this iteration 'ExtraItems' have been added to allow the player to obtain more items when the amount of owned items is low.

ID	Player Level 1	Player Money	Player Items 1	Player Level 2	Player Money	Player Items 2	Player Level 3	Player Money	Player Items 3
MAX	251	82	77	251	86	70	251	86	91
MEAN	219.1866267	23.44510978	29.46007984	219.1866267	23.85129741	30.19261477	219.1866267	24.71057884	32.90219561
MEDIAN	251	23	25	251	22.5	30	251	24	29.5
VARIANCE S	4347.164936	161.6618192	237.6072959	4347.164936	208.4364069	186.6232021	4347.164936	195.5744934	330.9055097
MODE	251	21	21	251	21	32	251	25	16

MAX ITEMS	157
MEAN ITEMS	31.56150699
MAX MONEY	155
MEAN MONEY	26.05559588

Figure 37

Comparing **Figure 37** to **Figure 33** the expected result that this iteration has not much effect on the average and maximum amounts of currency but instead creating more handles to control the average and maximum amounts of items a player has access to, gets showcased. This approach is a great starting point for the creation of predictable economic systems for

games. More detailed results can be found at https://philippstenger.com/wp-content/uploads/2019/02/Iteration4_ExcelDocumentation.7z.

Since how much this approach influences the amount of currency and items the player gets and needs during a playthrough can be controlled very precisely by increasing and reducing the effects of the negative feedback for having low and high amounts of currency and item, should this approach work for any game that fits the requirements of ‘Iteration 3: Scaling costs and reverse scaling gains while also stopping the scaling of gains on a specific level of progression’ as long the requirements can also be implemented for items.

7.5. Generalizing the evaluation of all prototypes

The results for all prototypes, can also be found at https://philippstenger.com/wp-content/uploads/2019/02/EconomySystems_ExcelDocumentation.7z. Based on these results it can be said, that handing more options to spend currency reduces the maximum amount of currency most players have, but this has only a small effect on the number and strength of extreme cases. Increasing the incentives for the player to utilize the options of will increase the percentage of players that get affected by this approach and increase the overall economic stability for the affected players. That being said it is not controllable how many players will utilize the additional options to spend currency. The prototypes for ‘Iteration 1: Additional purchases’ and ‘Iteration 2: Additional purchases with a higher chance based on game progression’ showcase this.

Limiting the total amount of currency and or items of the game shows no effect on the rate with which the player obtains and spends currency, but it does allow for more control about at which point during the playthrough the player is able to obtain a certain amount of currency and or items. That being said these approaches can lead to a situation in which the player has obtained all the currency and items the game has to offer, which can be problematic for many games. The prototypes for ‘Iteration 1: Fixed enemy count’ and ‘Iteration 1: Fixed valuables count’ showcase this.

The other approaches did focus on the creation of a negative feedback loop within the game world by adjusting income and spending of the player depended on the amount of currency owned. These approaches create a small-scale version of the effects that inflation has in the real world and how economic entities adjust to them. The overall result of these approaches was that they increased the stability of the system by creating a stable average and maximum value of currency and items a player has access to. But it can be hard to explain these approaches logically in the game world, since players are not used to increasing prices just because they have access to more currency.

The Prototypes can be found at: https://philippstenger.com/wp-content/uploads/2019/02/EconomySystems_MachinationsPrototypes.7z.

8. Conclusion

In this chapter, the results, considerations, and evaluations of the previous chapters get combined to create conclusions that allow answering the fundamental question of this work.

8.1. In-game economies

The economic systems of video games show many similarities with the economic systems utilized in the real world. The main difference between them is that in the real-world every economic entity wants to grow, while in the economic systems of games this is only true for player entities. The goals of all other economic entities of a game can be controlled to fit the goals of the design.

Because of this it is assumable, that the or at least one of the better approaches to create economic systems for games is, to create a system based on the rules and patterns that can be seen in real-world economic systems. This system should be tested for problems by utilizing tools like *Machinations*[69] and then be adjusted to fit the design goals utilizing the freedom given by the ability to control the economic goals of all non-player entities.

8.2. Controlling player possessions in video games

For this thesis, three different concepts to adjust game economies were tested utilizing six different approaches. These concepts are: Adding more possibilities to spend earned currency, limiting the overall amount of currency a player can obtain and introducing negative feedback loops[70] that scale on the amount of possessions a player has.

The overall evaluation of those tests are, that:
Adding more possibilities to spend earned currency leads to an overall decrease in the amount of possessions players have, but has no real effect on extreme cases.
Limiting the overall amount of currency a player can obtain does not affect the amount of possessions players have at all but creates fail states in which nothing is left in the game.
Introducing negative feedback loops[70] that scale on the amount of possessions a player has actively reduced the amount of possessions players have while also controlling the strength and amount of extreme cases, but can be problematic to explain to the player within the logic of the game world.

A more detailed overview for all prototypes can be found at: https://philippstenger.com/wp-content/uploads/2019/02/EconomySystems_ExcelDocumentation.7z.

The Prototypes can be found at: https://philippstenger.com/wp-content/uploads/2019/02/EconomySystems_MachinationsPrototypes.7z.

[69] (Dormans, n.d.)
[70] (Salen & Zimmerman, 2004, p. Chapter 18)

8.3. Use cases of controlling player possessions in video games

The use cases of the results of this work will usually revolve around a specific problem discovered during the development of a project and are therefore very project dependent.

Common problems this work will try helping to solve are adjusting NPC-merchant prices in a way that allows for interesting choices for the player, handing currency to the player in a way that allows it to be meaningful until the end of a game and the creation of economic systems meant for long-term use while allowing a for controlled level of inflation.

8.4. Application of the results of this work in financial in-game economic systems

It can be said, that based on the results of the evaluation of the created prototypes, it is possible to adjust the amount of currency a player is capable of obtaining and needs to spend within any duration of time. The problem is, that achieving this goal is often in opposition to the desired design goals of a project. Because of this, it becomes necessary to evaluate first if any given game has the need of controlling player income and spending. This can be decided based on the expectation, about how much the results of not controlling income and spending differs from the design goals of the game.

If it is deemed necessary that the financial economy of a game is placed in a controlled environment, it becomes important to decide what method is used to control it. The evaluation of the approaches created for this work can be used as a guideline for determining in which way one wants to restrict or react to the economic situation of the player.

For the creation of these approaches it is important to understand, that a game has the possibility to restrict the economic system in any way imaginable and can adjust all NPCs to have the economic goals the design needs them to have. But it is not possible to adjust the economic goals of the player within one game system. In most cases the economic goals of the player will align with personal economic growth, but it is possible that different games incentivise other economic goals.

Because of this, it can be said that the approach chosen to control income and spending in games must align with the set design purpose of the economic system and the economic goals players have within that system, while also achieving its original goal of controlling income and spending of the players.

8.5. Advantages the utilization of *Machinations*[71] offers to the game development process

The advantages this tool offers to the members of a development team are that it eases the communication between departments, since it allows to showcase the systematic structure of

[71] (Dormans, n.d.)

a game in a visually representative way. In addition to that, it allows for quick iterations by exchanging single structures in an already existing system. This tool also enables a team to work on the system simultaneously, since most changes to the system can quickly be explained to the rest of the team. Finally, it reduces the margin for human error, since the visual representation adds a layer of logic to the system in which problems can be spotted quickly.

The tool does also enable the developers to create tests of the base system of a game before the first gameplay prototypes are created and it is capable of running large playtesting sessions with simulated players. While there are already tools that allow for this *Machinations*[72] does so in a way that allows the whole team to understand why different changes must be made.

8.6. Inclusion of *Machinations*[72] into established pipelines

The tool allows for easy inclusion of the created data into already established pipelines. It does so by enabling the user to select and track specific variables of a created system. And export the data collected as a .xml file. This can be utilized by most common spreadsheet programs, at which point it is in an established pipeline.

That being said the inclusion of the prototypes into version control could be improved to allow multiple people to work on the same system at the same time. This could be done by allowing different prototypes to derive from each other.

[72] (Dormans, n.d.)

9. Future work

This chapter focuses on the additional work that has to be done to increase the reliability of the results of this work, while also handing out suggestions of how to expand from this work to new areas that utilize the results discussed here.

9.1. Extending economy prototypes for multiplayer games

The prototypes created for this work showcase only the economic systems of single player games. It is likely, that the economic systems created for single player games showcase the same results in multiplayer games, but with the addition that problems that appear for one player have the potential to spread to other players. This is a valid assumption, since during trade between players the economic systems of two single entities connect with each other. If this is repeated multiple times imbalances will likely spread between all players that interact with the trade system. But to confirm if this prediction is correct or to create a statement about what the actual results for multiplayer systems are further testing is required.

Doubling one of the economic systems created for this work and connecting them through trade possibilities is probably a good start for creating a system with two players. So the task becomes to create a way that connects a large number of systems with each other to simulate a large scale multiplayer environment.

A few of the necessary tests that must be concluded are: How will changes for one singular system affect all other systems; How will a change for each individual system affect the overall economic structure and How will changes to the trade connection or any other connection between the systems affect each individual system.

Another important task is to find out what possible ways exist to connects these systems other than trade. And what possible ways exist to utilize systems that consider multiple players as one economic entity with no sub-entities, which translates to one economic system that includes multiple entities with no otherwise separating connections between them. The game *Natural Selection 2*[73] could be a great start for this since it features two teams that each share their resources between team members. That being said it is a round based game, which makes it hard to utilize it for many tests for persistent games.

9.2. Extending *Machinations*[74] or similar tool to allow for better utilization of version control

For obvious reasons there is no problem for *Machinations*[74] to be included into version control systems. That being said, it is not possible to work on the same system simultaneously since one system is one file. A reason why someone could be interested in changing this to a system that allows to create multiple prototypes that derive from each other, is that it allows multiple designers to work on the same problem simultaneously without the necessity of creating

[73] (Unknown Worlds Entertainment, 2012)
[74] (Dormans, n.d.)

duplicates of one file. Another advantage for this would be that one large system could be split into many smaller systems to allow working on single problems to create one working system.

9.3. Creation of statistical observations for live games that utilize the in this work created prototypes

This work got its statistical results by conducting experiments and evaluating the data these experiments have given. But to further increase the reliability and the functionally of these results it is necessary to create observations from a live player base in a game that utilizes the conceptual structure of one of the in this work created prototypes and document how players react in this environment. This is necessary to find missing aspects in the created experiments, include player creativity to work around set rules and confirm the non-working elements of the prototypes in live games.

9.4. Creation of schemata of how to apply real-world economic approaches to economies in video games

This work focuses on explaining how whole economic systems work in games. But to properly utilize this to create a new game it becomes necessary that there is access to low-level schemata that showcase how to get a specific effect for the economic system of a game. These schemata could then be collected within a database that allows the design team to adjust the economic system of their game towards the desired direction by extending it with the right schema.

9.5. Confirmation that mathematical representations of economic concepts apply for games

There are already a lot of ways to represent real-world economic system mathematically. To use these calculations properly for games it becomes necessary to confirm if they work differently in games and if they do, in what way. This can be done by adjusting these calculations based on the differences between game economies and real-world economies mentioned in this work.

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