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Measuring Aggregate Production *in a Virtual Economy Using Log Data*

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Abstract

Virtual worlds contain systems of resource allocation, production, and consumption that are often called virtual economies. A virtual world operator has an incentive to monitor the economy, and users and outside observers benefit from temporal and cross-economy comparisons. Standard methodology of computing macroeconomic aggregates would allow this analysis, but such methodology is currently unavailable. I fill this gap by employing the concepts of national accounting. I focus on virtual economies where the production of new virtual goods takes place as the users expend inputs to produce predetermined outputs along predetermined production paths. Previous attempts at measuring the aggregate production of a virtual economy have been based on non-standard methods and externally collected data. In virtual economies the operator can collect extensive data automatically—a characteristic feature that should be reflected in any standard accounting scheme. Macroeconomic aggregates for a national economy are computed using the System of National Accounts, which is intended for measuring a national economy vis-à-vis the rest of the world. In a virtual economy context, by contrast, I make the distinction between production by the users and creation of goods by the virtual world code. These principles result in an aggregate measure called the Gross User Product, which measures the aggregate output of production activities by the users. I measure GUP for the virtual economy of EVE Online, based on extensive log data collected by the operator. The demonstrated method is generalizable for quantifying virtual economies on the macro level.

Keywords: virtual economy; economics; macroeconomic indicators; aggregate production; inflation.

Measuring Aggregate Production *in a Virtual Economy Using Log Data*

By Tuukka Lehtiniemi, Helsinki Institute for Information Technology

From an economic point of view, a virtual world becomes interesting whenever economic interactions exist between its participants. Most popular contemporary virtual worlds have a designed economic system of some sort. These systems mimic real-world economies: the users control virtual property, it may be possible to employ inputs to produce output, there are often markets in which outputs can be traded, and usually there is a virtual currency that is used as a mean of exchange. Sometimes there are non-desired phenomena like inflation (e.g. Castronova, 2001, p. 33) or hyperinflation (Simpson, 1999) that are, on the surface at least, similar to real-world economic phenomena. These observations have lead to naming the designed economies of virtual worlds ‘virtual economies’ (e.g. Bartle, 2003; Burke, 2002; Castronova, 2001).

Virtual property and the spaces in which they can be found are digital, and exist as entries in a service operator’s database. Many of the popular virtual worlds are called ‘games’, a label that has connotations of trivial or negative effects on ‘real’ life (Yee, 2006, p. 38). When assessing economic value, these facts should be irrelevant: willingness to pay and sacrifice time should be seen as the ultimate arbiter of significance (Castronova, 2002, p. 15). Virtual objects carry actual, real value. This value is realized via the phenomenon called real-money trading of virtual property. One estimate placed the volume of real-money trading of virtual items to USD 2.1 Billion, globally, in 2006 (Lehtiniemi, 2007). New possibilities for economic analysis have opened with the phenomenon: for example, economic experiments have been conducted in virtual worlds (Chesney *et al*., 2007; Nicklisch & Salz. 2008), and the determinants of prices on secondary markets for virtual property have been evaluated (Castronova, 2004).

The users participate in a virtual world voluntarily, and usually pay for the privilege in some form. A working and sufficiently stable economy is arguably instrumental to a satisfactory user experience. Currently, there are no standard measures of the state of a virtual economy. Using quantitative measures, the operator could monitor the outcomes of design changes. The measures would enable economic modeling, a prerequisite for predicting implications of intended changes. Such measures would benefit the users by offering detailed economic data for decision-making purposes, and outside observers would be interested in comparative analysis between virtual economies.

In this article, I develop a standard way in which operators can quantify virtual economies. The focus is particularly on measuring the level of economic activity. Unlike the operator of a virtual world, who can duplicate any virtual goods in the virtual world essentially free of cost on the margin, the users act under strict budget constraints, and their actions are those that are paid attention to. As a first approximation, the operator can follow the number of users and the time spent in the virtual world. Better measures, such as an aggregate production measure, allow the operator to do more detailed comparative analysis within the virtual economy. An aggregate production measure was actually an important part of one of the first studies of virtual economies (Castronova, 2001).

I take a more rigorous approach to measuring aggregate production of the users, one based on employing the possibility of gathering comprehensive production data from a virtual world. My requirements for the aggregate production measure are as follows. Firstly, it has to represent the activities of the users. Secondly, it has to allow for comparative (for example, temporal) analysis within the virtual economy. Thirdly, it has to enable quantification of effects of design changes and the use of economic models. And finally, it has to allow for some sort of comparative analysis between virtual economies. My approach is based on the principles of the United Nations System of National Accounts (SNA), according to which internationally consistent macroeconomic accounts (for example, GDPs of national economies) are formed. As will be shown, SNA cannot be directly used for measuring virtual economies, but it makes sense to employ its tried principles.

In this article, I first outline what I mean by a virtual economy and what basic economic concepts, such as production, mean in its context. Next, I develop an accounting system for measuring the value of goods and services produced by the users during a period of time within the boundaries of a virtual economy. I employ standard macroeconomic flow chart analysis for this purpose. The developed accounting system draws from SNA, but stresses production by the users, as opposed to production within a national economy. Finally, I show how the aggregate production measure can be computed in practice, employing comprehensive production and market data logged by CCP games, the operator of the virtual world called EVE Online.

To my knowledge, my approach and the employed data are unique in the field.

Virtual Economies

The acts of designing economy-resembling activities and then giving them the label ‘economy’ does not invoke an economy – at least in the sense that the term is used in the context of economics. For example, the possibility of purchasing virtual goods from the service with set prices does not justify calling the service a virtual economy. Analogously, using the term ‘physics’ to describe the outcome of a computer program that automates the rules governing movement of virtual objects in virtual world does imply there are physics inside the virtual world.

Definition

According to a textbook definition, an ‘economy’ is a system that determines what is produced, who produces it, and who consumes the products (e.g. Stiglitz & Driffill, 2000, pp. 9-10). The decisions and choices are made subject to scarcity. The products can be goods or services. Economies are often, but not necessarily, thought to exist inside certain geographic boundaries. A national economy and the Robinson Crusoe economy make intuitive sense with respect to this definition.

A virtual economy, then, is a system that determines what is produced—as well as by whom, and for whom. The products are virtual goods or services, and the production happens when a user expends inputs via an online service. Instead of geographical boundaries there is an architectural (cf. Lessig, 1999, p. 25) boundary: the scope of one virtual economy is the extent of the context in which the products can be consumed. For a virtual economy to exist in an online service some sort of production must be possible – the users have to be able to employ inputs to create outputs. For the allocation part to be possible, the users have to be able to exchange the products.

A virtual economy emerges naturally in a typical virtual world in which in which the following holds true. There must be massively many users, users that use their ultimately scarce resource of time to gain possession of virtual items, and there must be many more virtual items than any one user may earn by simple time investment. Finally, there must exist possibilities of exchanging these items with other users. Some mechanics may have a role as a catalyst for economic phenomena: for example the mechanics of a virtual world are often designed so that specialization is possible, encouraged, or compulsory. Despite this, a virtual world is not what justifies the existence of a virtual economy, and neither are the designed mechanics such as the sales of virtual goods by the operator. The users' employment of inputs to create outputs, the resulting forms of virtual property and services, and their exchange are what invoke the economy.

Economic Agents

The economic agents of a virtual economy can be divided into two classes. In all virtual economies there are characters (avatars) that are the users' representations in the economy. Often there are also NPCs (non-player characters, e.g. Bartle, 2003, p. 287), characters operated by computer code, some of which take part in the economic transactions in the world (see e.g. Simpson, 1999). Typical examples of such NPCs are the ones that partake in market transactions with the users.

There is a fundamental economic difference between the user characters and the NPCs. The former operate according to a budget constraint, whereas the latter do not (at least not necessarily) – for example an NPC shopkeeper does not necessarily make profits (e.g. Simpson, 1999). Instead, they supply and demand goods for a fixed price, creating and erasing goods and currency – or the relevant database entries – based upon need. The presence of the NPCs gives rise to what have been called (Simpson, 1999) two overlapping economies: the player economy and the NPC economy. The importance of the NPCs varies: they are almost nonexistent in some virtual economies, and a major purchaser of some produced goods or the major supplier of some goods in others.

Production of New Virtual Goods

In terms of production, virtual worlds can be roughly divided into three types. The first type is characterized by a lack of production of new virtual goods. Habbo, a social world targeted at teenagers, is one example: virtual goods enter the circulation as the users purchase dedicated virtual currency from the operator, and then use this currency to buy virtual goods, again from the operator. Instead of expending inputs to produce output, the users consume income from other sources on virtual goods. In the second type, predetermined virtual goods can be produced via predetermined production paths. The operator designs the goods and the production paths. This is probably the largest virtual world type; most massively multiplayer online games, for example World of Warcraft, fall into this category. In the third type the users can create genuinely new kinds of virtual goods and make technical innovations regarding production paths. The non-game virtual world Second Life, in which the users can use their graphic design and coding skills to design and implement new virtual goods, is one example (e.g. Ondrejka, 2004, pp. 4-5).

The focus of this article is on virtual worlds of the second type. Two methods of production of new virtual goods can be identified for such virtual worlds (Simpson, 1999). The first method mimics production processes of physical goods: the users produce raw materials and refine them into final goods, possibly through multiple stages of intermediate production and via inputs of multiple, specialized users. The raw material production typically happens by mimicking some real-world raw material production process, such as mining of ore. The second method does not have direct analogy in physical good production. As an example, a user locates a NPC monster, and attacks it. If the user is successful, there is a possibility that a new good appears, as if 'dropped' by the NPC. The process can be thought of as somewhat resembling hunting, except that the proceeds of the hunt can be final goods. (See Simpson, 1999).

An Existing Measure of Aggregate Production

The only previous transparent aggregate production measure for a virtual economy has been computed for an online game called EverQuest (Castronova, 2001). This measure has been quoted widely, and it is therefore worthwhile to investigate it thoroughly. Due to unavailability of direct production and expenditure data, Castronova measured aggregate production based on data from a survey and from the secondary real-money trade market. It is useful to break down the underlying method as follows:

Each character in EverQuest has an indication of advancement, a level, associated to it. Castronova used USD prices, gathered from the Internet auction site, of characters to form a price for one character level (p) by regressing observed price against level. Based on survey responses, he determined the number of hours (h_l) a user uses, on the average, to gain a level by regressing the gained levels on the amount of time used. Finally, the average number of concurrent users in EverQuest (N) and the number of hours in a year h_a yields an estimate of the total USD value created in a year (here called V) in EverQuest:

$$V = N \frac{p h_a}{h_l} \qquad (1)$$

Dividing V with the average concurrent users (N), Castronova ends up in an aggregate *per capita* production measure, or what he calls GNP *per capita* of EverQuest. He compares the *per capita* figure to the *per capita* GNPs of real-world economies and argues, perhaps half-seriously, that the virtual world of EverQuest is the 77th richest country in the world (Castronova, 2001, pp. 41-42).

If the last step, division with the concurrent users N , is carried out on the above equation, the *per capita* measure can be written as

$$\frac{V}{N} = \frac{p h_a}{h_l}. \qquad (2)$$

Hence, Castronova's aggregate production *per capita* is a function of only two variables: the price of one character level and the number of hours used per level. A *caput* is assumed to stay online around the clock, producing h_a/h_l levels, each of value p, per year. In contrast, *per capita* measure of GNP is GNP divided by the total population (e.g. Begg *et al.*, 2003, p. 285). The reports on 'virtual world GNP' numbers tend to, unsurprisingly given the comparison to GNP *per capita* of national economies, first present the above *per capita* value and next discuss the total number of users (e.g. BBC, 2002). This implicitly inflates the total monetary value.

Even if the *per capita* methods were comparable, are national economies the best standard of comparison for virtual economies? Such a comparison is a statement of similar value as the statement that the output of a firm is equivalent to some share of the GNP of some national economy – that is, it has value as a provider of context.

A measure based on external prices is not reliable for any comparative analysis, be it within the economy or between economies. These prices can fluctuate irrespective of what happens inside the virtual economy: for example, the operator may revise their policy towards real-money trading, making selling riskier. *Ceteris paribus*, supply curve shifts upward and prices rise accordingly. If aggregate production inside the economy, in real terms, remains constant, its external value rises.

With the available public data, Castronova's measure may be a good proxy for the USD value creation inside EverQuest. It should not be called GNP, however, and it should not be compared to GNP values of national economies as if they measured something directly comparable. Due to its method of computation, the operator cannot effectively use the measure for monitoring purposes. A better approach, and one that can be readily taken by the operator, is to rely on the principles of national accounting. As will be shown below, production and expenditure data collected inside the virtual economy can be employed towards this end.

A New Measure of Aggregate Production

A Simplified Flow Diagram

Let us first consider only the manufacturing activities of the users. In this simplified situation the production activities can be presented in the circular flow (cf. Begg *et al.*, 2003, p. 275) in Figure 1. Instead of the standard sector division (households, firms, and government), the activities of the agents in the economy are separated into two roles: an agent can act either as a producer or a consumer. A producer is not necessarily associated with any firm that pays wages to its employees: instead, each agent in the economy has a dual role. Each of them may act at some point in time as a producer, and in another point as a consumer. An agent may produce items to be sold on the market, or produce items for her own use. In national accounting, the latter is called own-account production (United Nations [UN], 2003, p. 24). Like market production, own-account production is valued at market prices or, if market prices are not available, using production costs (United Nations [UN]. 2001). In a virtual economy, the share of own-account production is potentially large – a large share of total income is paid in kind by the producer role to the consumer role. The agents may be thought of as entrepreneurs who produce items both for the market and for own consumption.

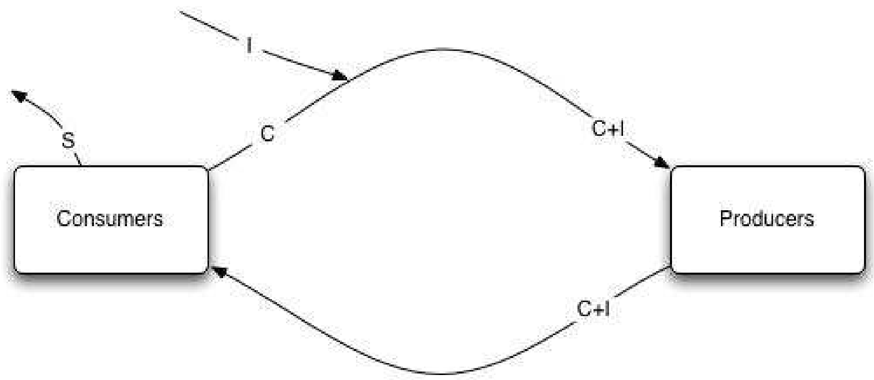

Figure 1 Simplified flows of expenditure and income.
The users' activities have been divided into two roles.

In Figure 1, the upper arc of the flow diagram represents total expenditure, and the lower arc represents total income. The producers produce the final goods and services according to the total expenditure consisting of final consumption C and investments I. The interpretation of C, I and savings S are standard (see e.g. UN, 2003, p. 25). The aggregate production in this economy would equal the value of $C+I$ in some period of time. Since there are no flows out of the system, aggregate production can be measured either as aggregate factor income or as aggregate expenditure.

There is also the alternative form of production, which was introduced as the drop method. Introduction of this new mean of production does not require adding sectors or flows to the flow diagram, but it may make differentiating between consumption C and investments I difficult. The outwardly same use of a good can often be categorized as either consumption or production. For example, when users purchase weaponry, they may use their purchases for consumption by attacking other users. Alternatively, they may attack NPCs and produce new goods. In this case their purchase was an investment.

The Environment

The flow in Figure 1 is, naturally, an overt simplification. The users are usually not the only agents that participate in the flows of expenditure and income. There is also a sector that represents the operator of the virtual economy. I shall refer to this sector as the Environment. The Environment is a metaphorical entity that collectively represents everything that is not operated by the users. In practice, the Environment may include for example code-operated sellers of intermediate goods.

When users produce something by gathering raw materials, refining them into intermediate products, and finally producing a virtual final good, the value of the final good represents all value additions through the production process and all received incomes of the participants of the production process (Figure 1). If an intermediate good is purchased from the Environment, its value is still reflected in the value of the final good, but there is no corresponding income received by any consumer. The Environment sector, then, affects the manufacturing flows as presented in Figure 2. The purchases of intermediate and investment goods (E_m) from the Environment leak out of circulation. The most closely fitting analogue for the Environment in SNA is the foreign sector. In national accounting, intermediate goods bought from the foreign sector are subtracted from the total expenditure, as they are not associated with corresponding factor incomes inside the national economy. Treatment of E_m should be similar to exports: subtract the value of all intermediate goods purchased from the Environment.

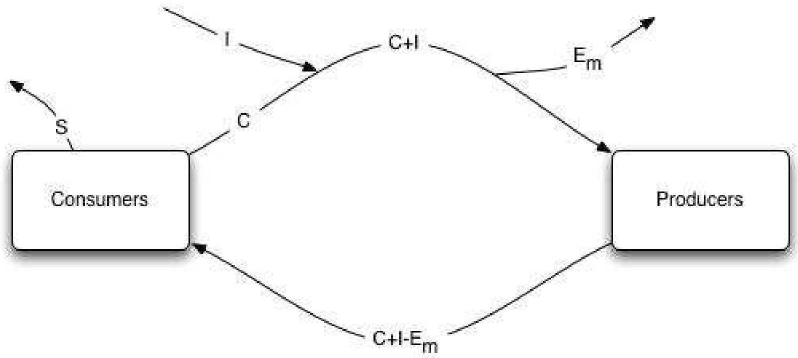

Figure 2 Expenditure and income with part of intermediate and investment goods (E_m) flowing out of circulation.

In a national economy, a relevant borderline can be drawn between domestic and foreign production (or receiving of income). The former are included in GDP, whereas the latter are not, explaining the 'domestic' part in GDP. This distinction is clearly not relevant for a virtual economy. When measuring the users' production activity in a virtual economy, a relevant borderline exists between the production the users and the creation of goods by the service in which the virtual economy takes place. I will, from now on, call the measure of the aggregate production in a virtual economy the *Gross User Product*, or *GUP*, of the economy.

Further Roles of the Environment

Purchaser and seller of goods.

The role of intermediate and investment goods purchased from the Environment was discussed above. The reciprocal role of sales of these goods to the Environment is clear: they represent income to the users, but do not show up in the prices of final goods. Their value should, then, be added to the GUP, giving rise to a new item E_x.

When the Environment sells final consumption goods, their value represents consumption expenditure flowing out of the system, similarly to consumption good imports in SNA. When the Environment purchases user-produced final goods, they should be treated similarly to goods exports in SNA - they give rise to factor incomes to users but do not show up in either consumption or investment expenditure. All final good purchases from Environment are, then, included to the term E_m and all final good sales to Environment to the term E_x.

Using these principles, the treatment of various kinds of goods purchased from and sold to the Environment can be decided on. The foreign trade analogy suits production of goods for the purpose of selling to the Environment. It also suits goods that may not be consumed nor produced inside the economy, but can be purchased from the Environment, transported, and sold again to the Environment with a premium – much like goods that are transited through one country to the next country. The transit gives rise to factor incomes, and the added value of such transit should be reflected in GUP.

Purchaser and seller of services.

One of the economic roles of the Environment is to purchase services from the users. The Environment may, for example, provide task for the users to complete. The payouts of theses tasks should be included in GUP: the users use time and other inputs to produce a service, which they sell to the Environment. The payouts flow to the users as incomes, but the flows do not originate inside the economy. The effect is similar to exports in national accounting, and their value should be included in E_x.

The Environment may also sell services. For example, the users may be able to hire an NPC to sell their virtual goods (Simpson, 1999). The services may be either final services, in which case a part of final consumption expenditure flows out of circulation, or intermediate services, in which case they drive a wedge between expenditure and income. Both types of services have an effect similar to imports in SNA, and should be included in E_m. Sometimes these services may be presented in guise of taxes.

Collector of taxes.

In addition to the many foreign-sector-like roles, the Environment also performs actions that bear resemblance to the actions of a public sector. The users often pay compulsory fees that resemble taxes. For example, each transaction event on the market or each manufacturing event may be subject to a fixed or proportional tax. There are other similar compulsory payments, though they may not always be called taxes.

In the national accounting context there is, however, an important difference between these tax-like payments and taxes collected by the public sector in a real-world economy. The Environment sector does not usually operate subject to a budget constraint (Bartle, 2003, pp. 265-266), and therefore it does not actually redistribute income by means of taxes and subsidies. The tax-like payments made to the Environment sector trickle out of the macroeconomic flow of expenditures and incomes. Their role is actually just this: they remove money from circulation, enabling control on the money supply.

A government sector is absent from the macroeconomic flows depicted in this study. Instead, in the accounting sense, taxes and similar payments resemble imports of services more than anything else. In one important sense taxes in virtual worlds do conceptually resemble taxes: a tax payable by the producer on sold goods drives a wedge between prices paid by the consumers and received by the producers.

The Gross User Product

The roles of the Environment are summarized in the macroeconomic flows in Figure 3. The new flows include the value of goods and services purchased by the Environment (E_x); net non-investment payments, such as market taxes, that the producers make to the Environment (E_p); and net tax-like payments the consumers make to the Environment (E_c). The flow E_m is augmented with the components described above.

In the flow chart of Figure 3, GUP can be viewed as the sum of user expenditures depicted on the upper arc. Summing the expenditure components yields

$$GUP = C + I + E_x - E_m . \qquad (3)$$

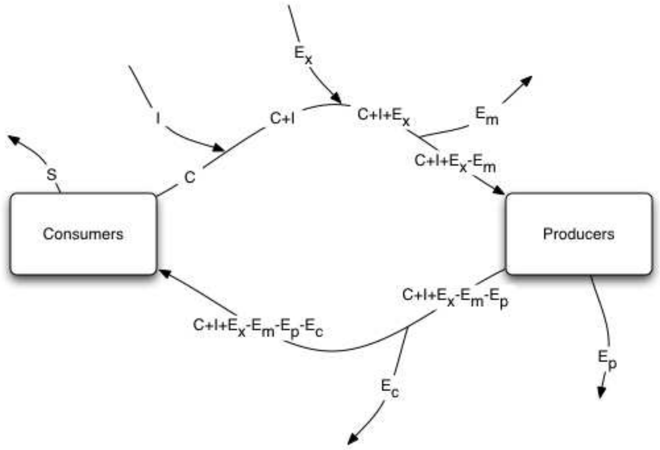

Figure 3 Complete flows of expenditure and income in a virtual economy.

This, on an abstract level, is the basis for GUP measurement. GUP consists of expenditures on consumption and investment, and net sales of goods and services to the Environment sector. The equation resembles the standard expenditure equation describing the GDP components (e.g. Stiglitz & Driffill, 2000, p. 397).

Conditions of a specific virtual economy obviously affect what, exactly, the terms in the GUP equation should include. These conditions also affect the valuation principles: market taxes and other fees can induce producer and consumer price discrepancies, and the exact mechanisms of trading may affect determination of market prices. I present an example of practical GUP measurement in the following section.

Measuring Gross User Product

I use EVE Online (EVE) as an example virtual economy for which GUP is computed. EVE, an online game set in a science fiction background, is run by CCP Games based in Iceland. It had about 220,000 paying users at the end of the year I consider (2007) (Guðmundsson & Halldórsson, 2008, p. 4). It is targeted at a mature audience, the average player age being 27 years (Lehdonvirta, 2006).

The Western market is covered by a single instance of the virtual world of EVE. All users are, then, agents in the same economy. This makes the economy large in comparison. Though there are games with vastly more users, their user bases are typically distributed among several instances of the game world, so that a few thousand users can potentially interact with each other in any one instance. The users of EVE pay a subscription fee of around 15 € per month to gain access to the game. The operator does not directly sell virtual property, but an unsanctioned secondary market exists on for example several dedicated Internet marketplaces.

I employ market and production data from a database collected by CCP Games and made available to researchers by a collaboration agreement (see HIIT, 2007). Relevantly to the topic at hand, the database consists of, in principle, a complete set of production and user-to-user and user-to-Environment transaction data from the EVE economy within the time period from January to June 2007.

Production and Valuation

According to its story, the virtual world of EVE is set in distant future. The forms of virtual property include spaceships, high-tech equipment, exotic minerals and metals. Production of new virtual goods in EVE happens by the manufacturing and the drop production processes. Many, though not all, final goods can be produced from intermediate goods by the users. Production happens via predetermined production paths. The drop-type production takes place as the users receive virtual goods that appear upon destroying various kinds of NPCs. Users produce also services, for example complete scripted tasks called missions, or locate and destroy NPCs for a reward.

A large part of trading in EVE happens using a built-in market feature. The ‘market’ is an exchange where users list buy and sell offers. The goods are priced using the virtual currency of EVE, called ISK. Perfect information on the goods is available, and the platform offers a trusted way of completing transactions. In SNA, market prices are used for valuation of goods (UN, 2001). I use the periodically averaged prices agreed upon using the market feature as market prices. There are also other ways of completing transactions: users can barter and set up auctions. Prices agreed upon using these features may be ambiguous: many goods can be bundled together. They are also more likely to be economically non-significant, that is production and purchase decisions are based on arrangements other than the price.

Transactions using the market feature are subject to a varying proportional market tax payable by the party listing the buy or sell order. The market prices, then, have properties of both producers’ and purchasers’ prices. Despite the discrepancy between what the purchaser pays and the seller gets, the market prices shall be defined as the prices observed on the market, inclusive of taxes. To correct some of the error introduced by this definition, the taxes actually paid are excluded from GUP. These taxes most closely correspond to the term E_p in Figure 3. This yields Equation 4 as the GUP measurement basis:

$$GUP = C + I + E_x - E_m - E_p \,. \qquad (4)$$

A source of error is introduced here: the market tax and collected regardless of whether the exchanged good is a freshly produced good or a second-hand good. The market tax size is small, however, and the errors introduced are insignificant in practice (see Table 1).

Market prices are not always available for seldom-exchanged goods. The SNA approach to valuing such production is to use production costs as the second-best alternative (UN, 2001). Production costs are defined as the sum of intermediate consumption, compensation of employees, consumption of fixed capital, and net taxes on production (UN, 2003, pp. 21-22). In this analysis, the production costs include intermediate goods and partially used fixed capital goods using market prices. Compensation to other factors of production is not considered.

Measurement Practices

Above, it was discussed that investment and consumption expenditures may be impossible to separate reliably. This is the case in EVE Online. A breakdown of final expenditures to investment and consumption shall not be attempted in this analysis. The approach to measuring GUP that I employ is based on a combination of the production approach and the expenditure and income approaches (UN, 2003, p. 5). The value of produced final goods, including consumption and investment goods, is measured by observing production events. The products are valued using market prices. This also includes the values of input intermediate goods. Then, referring to Equation 4, the remaining items are identified and their contribution to GUP is measured using expenditure and income data.

The value of manufactured goods is measured by observing the manufacturing events and using the valuing convention outlined above. The goods produced by the drop method are measured by a probabilistic approach, based on the number of destroyed NPCs and the probability of the appearance of different goods. Measuring the value of the newly produced final goods will end up including user consumption of user-produced final goods, user-produced fixed investments, and user-produced final consumption and final investment goods sold to the Environment.

These items should be included in GUP, with two reservations. First, some final goods must be produced from other final goods. The final goods used up in the production process are subtracted from the total value of produced final goods. Second, the value of investment goods purchased from the Environment is included in the prices of final goods. Intermediate goods are easy to identify, but, as discussed previously, it is difficult to separate investment from consumption. I considered a subset of purchases from the Environment as likely to be made to add production capacity and regarded them as fixed investments. There is a subjective element in this classification, and some error is likely introduced.

When the user-produced final goods have been included and the above corrections made, the next step is to compare the outcome of this production approach to Equation 4. The value of produced items together makes up a part of each of the items C, I, E_x, and E_m, but does not complete GUP. To complete it, some items need to be added, including the value of intermediate goods sold to the Environment, the total value of services sold to the Environment, and the net value of transit goods sold to the Environment. All three are measured using expenditure data. Finally, the paid market taxes (the term E_p) are deducted from the resulting figure to end up in GUP as defined in Equation 4.

There are two omitted categories of production that are not, but should be, included. These production types are the services users sell to other users, and increases in stocks of intermediate goods. Both are left out due to practical difficulties—that is, the unavailability of data. This obviously introduces some error in the GUP measurement.

GUP at Current Prices

The available data allows for GUP computations for the time period between the beginning of January 2007 and the end of June 2007. The GUP in June 2007, and its main components, is presented in Table 1. The total GUP of that month is $3.47*10^{13}$ ISK, or 34.7 Trillion ISK.

Table 1 Breakdown of GUP in June 2007.

Component	Value[a]	Contribution[b]
Net manufactured final goods	18.6	+
Final goods dropped by NPCs	10.9	+
Services sold to Environment	11	+
Net goods from Environment	5.4	-
Market taxes to Environment	0.4	-
GUP total	34.7	

[a] value in trillion ISK

It is evident that the main contribution to GUP comes from produced final goods (including both production methods). The net good 'imports' from the Environment include mainly investment goods purchased from the Environment, intermediate goods both purchased from and sold to the Environment, and the added value of transit goods. The selected month is representative: the changes in the component shares have remained within three percent units over the six-month period.

The error induced by the subjectivity regarding the inclusion of items in the fixed investment category is relatively small. Assuming the value of fixed investments from Environment increases or decreases by 20 %, the GUP value of June 2007 would decrease or increase (*ceteris paribus*) by around 4 %, respectively.

The main problem of the GUP presented in Table 1 is that it is not in any context. Is the 34.7 Trillion ISK a large or a small number? How has GUP evolved over the past months? There are two ways that both partially solve the first of these problems. The first way is to measure the total value of all goods in the users' inventories. Currency is excluded from this value. In the end of June 2007 this value was, using current prices and the valuation principles employed in the GUP measurement, roughly $1.74*10^{15}$ ISK. The GUP of period 6 is about 2 % of this total figure. The accumulated wealth in the economy is significant, especially considering the fact that GUP represents production in gross terms. The other way is to convert the GUP of June 2009 to US dollars. Unfortunately, reliable statistics of exchange rates from ISK to USD are not available. Something giving an idea of the order of magnitude of the exchange rate can be found by looking at the lowest sell offers listed on one publicly available real-money trading platform[1] of the time. These varied between USD 50.00 and 53.18 for one billion ISK during June 2007. The USD value of GUP in that month, using the lowest exchange rate, would be around 1.74 Million. The number of users (total, not concurrent) in EVE at the time was 172,000 and, therefore, the monthly GUP per user was around USD 10. The potential error introduced by the exchange rate uncertainty cannot be overstressed.

[1] Sparter.com, a site that is not operational anymore. The price data was collected from the website during June 2007. These prices represent listed sell offers, not necessarily realized transactions. Additionally, all completed transactions were subject to a 20 % brokerage fee.

The second of the problems calls for further analysis. Monthly GUP numbers as such are not comparable: if the overall price level has changed, nominal GUP may change differently from the real GUP, and the changes in aggregate production are veiled by the price changes.

Deflated GUP and Economic Growth

To allow for growth considerations, GUP has to be purged of price changes. One of the most closely watched price statistics (Wynne & Sigalla, 1994, p. 1), consumer price index (CPI), is an immediate suspect. A CPI is not available on demand for the EVE economy. CPI is not an optimal measure either: the changes in patterns of user expenditure are potentially very fast in the EVE economy, much more so than in a national economy. For example, when the operator introduces an update including new goods or new production paths, it can have a significant effect on the users' expenditures, essentially overnight. CPI is based on samples – due to practical reasons – and unable to react quickly to shifts in expenditures (e.g. Wynne & Sigalla, 1994, pp. 4, 13).

The index to be chosen here has to be able to accommodate for substitution effects in consumption due to introduction of new goods, but be easily calculable and interpretable. One index that fulfills both requirements is a chained Fischer index F_C (Forsyth & Fowler, 1981, p. 228). The index at period t, F_C^t, is based on the prices p and quantities q of exchanged goods on periods t and $t-1$. Technically, the Fischer index is a geometric mean of two indices, the Paasche and Laspeyres indices (Ibid.), at the period under consideration:

$$F_C^t = \sqrt{\frac{\sum_i p_i^t q_i^{t-1}}{\sum_j p_j^{t-1} q_j^{t-1}} \frac{\sum_i p_i^t q_i^t}{\sum_j p_j^{t-1} q_j^t}} \qquad (5)$$

The chained Fischer index recognizes that quantities may change during the interval between two successive periods. The prices and quantities considered here are those of exchanged final goods. The underlying logic is that as the utility arising from consumer goods and services defines the prosperity of an economy, the prices of these products should be the basis of measuring inflation (Bryan & Pike, 1991). As was discussed above, the users are not only consumers of final goods – they use the very same goods also for production. Therefore, some purchases affecting the bundle in the index will actually be investments instead of consumption.

The monthly inflation in the EVE economy, $F_C^t \mid t \in 1...6$, is presented in Figure 4. During the investigated six-month period, inflation has actually been negative – the economy has experienced deflation. Deflation has been increasingly fast. A constant monthly deflation of 6 %, for example, translates to a yearly deflation of more than 50 %. The reasons underlying the deflation can be numerous, including the usual suspect of real output increasing faster than the stock of money (e.g. Schwartz, 1973, p. 264).

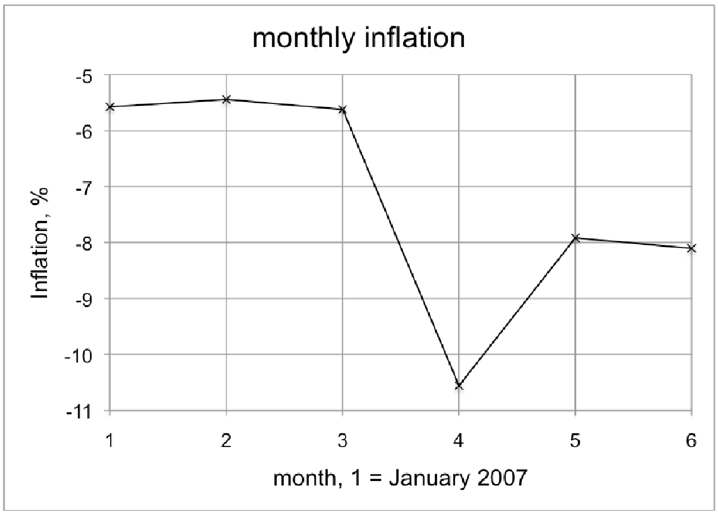

Figure 4 Monthly inflation rates in the EVE economy. The observations span the period between January 2007 (period 1) and June 2007 (period 6).

It is now possible to return to the analysis of GUP values computed in the previous section. The periodical GUP at current prices (GUP_{cur}^{t}) can be deflated to the first period (GUP_{def}^{t}) using the principle of chained multiplications of the chained Fischer indices (cf. Forsyth & Fowler, 1981, p. 228):

$$GUP_{def}^{t} = GUP_{cur}^{t} \prod_{j=2}^{t} F_{C}^{j} \qquad (6)$$

The deflated GUP from January 2007 to June is presented in Figure 5. In that figure, the actual values of GUP are replaced by an index comparing the GUP values to the value in the first period. Before indexing, all values of GUP are deflated to period 1—that is, to January 2007, using Equation 6. The effect of varying month length has also been purged.

The index of GUP does not, however, take into account the increase in the number of users. The user base, measured by the number of paying users, has grown about 12 % during the investigated six-month period: from about 154,000 in January 2007 to about 172,000 in June 2007. As the user base of EVE Online has increased during the investigated period, some part of the GUP growth comes from the increased number of users and the rest from increased production efficiency. The deflated monthly GUP purged of the effect of increased user base is also presented as an index in Figure 5. The method assumes a temporally constant input time per user.

During the half-year period the monthly GUP has increased around 70 % and the monthly GUP per user over 50 %. The monthly growth rate of GUP per user has varied through the investigated period, being about 1 % from January to February and reaching over 13 % from March to April. The latter figure is significantly high; it gives rise to a yearly growth of over 300 % assuming constant growth rate. The increase in production efficiency, measured in terms of average GUP produced per user, has been significant.

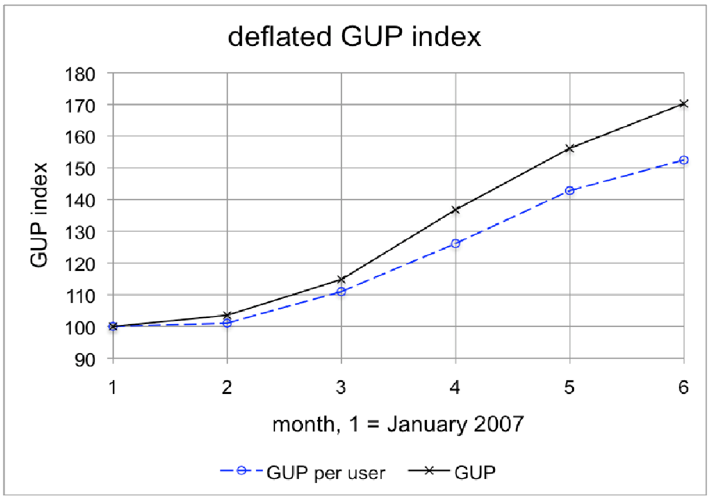

Figure 5 Deflated monthly GUP and deflated monthly GUP per user between January 2007 (period 1, index value = 100) and June 2007 (period 6).

Conclusions and Discussion

I have shown that the principles of SNA can be used to form an accounting scheme for measuring the aggregate production activities of the users in a virtual economy. The main difference in national accounting and virtual economy accounting lies in the definition of what is considered as relevant production to be included. Gross domestic product, as defined in SNA, is intended for measuring the production that takes place in some geographic location. The borderline is drawn between domestic and foreign production. In a virtual economy, the physical 'where' of a production event is meaningless, and the 'domestic' metaphor is not usable. The main finding of this study is that the borderline has to be drawn between the users and the service they use, or the Environment. The name of the SNA-based aggregate production measure, the Gross User Product, emphasizes the relevance of the users as producers, as opposed to the creation of new goods by the Environment.

Once this distinction is made, it is straightforward to compute the GUP. SNA is referenced in all stages, but instead of value added in the domestic sector, the value additions by the users are included. The applicability of this method was demonstrated for the case of EVE Online using transaction and production data provided by the operator firm. A chained Fischer index was employed to purge the GUP measure of the effects of deflation. The ability to centrally log the necessary data for the computations of these measures is a distinguishing feature of virtual economies.

The real GUP growth rates purged of the increased number of subscriptions show that the users' production efficiency has increased. From the operator point of view, this increase can mean that they have to introduce new virtual goods and production paths to compensate for the decreasing required effort level. The production efficiency also offers one explanation for the observed decrease of overall price level, or deflation: as the productivity increases, the prices can be expected to fall in the long run.

GUP performs well against the requirements for an aggregate production measure laid out in the first section of this article: it measures the production activities of the users; it can be used for virtual economy -specific comparative analysis by the operator; it can be used for monitoring and predicting design changes; and it can be used for comparative analysis between virtual economies. The measured GUP shows that these requirements can be fulfilled also in practice. The six observations of monthly GUP, and the five observations of GUP growth that can be derived from this data, form a very short time series that does not allow for, as an example, time series modeling of economic growth. This is a practical consideration, and nothing that an operator could not overcome.

The previous publicly available aggregate production measure, Castronova's "GNP", was oriented at approximating the US dollar value of production in a virtual economy. As was shown, it does not perform well against the requirements outlined for an aggregate production measure in this article. This is particularly true for the requirements in connection with economic monitoring, prediction and comparisons. In addition, some drawbacks in Castronova's method of producing *per capita* numbers were indicated. As tempting as it may be, comparing numbers produces by Castronova's method and the GUP method is practically meaningless. This would be true even if the per capita methods were comparable. Comparisons using the USD value of production in virtual economies will end up, for a large part, comparing the state of the real-money trading markets, and not only the state of the virtual economies.

The focus of this study was in virtual economies where production of predetermined new goods happens along predetermined production paths. The principles used for GUP computation in this study are directly applicable to other virtual economies with production methods comparable to the ones considered here. Such virtual economies include the majority of large game-like virtual world in the Western market. Virtual economies with different production methods were not considered, but there is no reason why the same principles could not be used. Users will be the relevant producers, and the Environment will have a role similar to the foreign sector in national accounting. The extent of the role of the Environment is obviously different in different economies.

Reliable comparative macroeconomic analysis between virtual worlds is not currently possible. If GUP was used as a standard measure of aggregate production, not only would the possibilities of internal economic modeling be enhanced, but cross-economy analysis of production performance would be enabled. GUP, then, opens possibilities for standardized analysis that have not been available before.

Bibliography

Bartle, R. A. (2003): *Designing Virtual Worlds*. New Riders, Boston.

BBC (2002). Virtual Kingdom Richer Than Bulgaria, *BBC News*, March 29. Online: http://news.bbc.co.uk/1/hi/sci/tech/1899420.stm

Begg, D., Fischer, S., and Dornbusch, R. (2003). *Economics*, 7th edition, London: McGraw-Hill.

Burke, T. 2002. *Rubicite Breastplate Priced to Move, Cheap: How Virtual Economies Become Real Simulations*. Unpublished manuscript. Online: http://www.swarthmore.edu/SocSci/tburke1/Rubicite%20Breastplate.pdf

Bryan, M. F., and Pike, C. J. (1991). Median Price Changes: An Alternative Approach to Measuring Current Monetary Inflation, *Economic Commentary*. Federal Reserve Bank of Cleveland, December.

Castronova, E. (2001). Virtual worlds: A First-Hand Account of Market and Society on the Cyberian Frontier, *CESifo Working Paper Series.* No. 618.

Castronova, E. (2002). On Virtual Economies, *CESifo Working Paper Series.* No. 752.

Castronova, E. (2004). The Price of Bodies: A Hedonic Pricing Model of Avatar Attributes in a Synthetic World. *Kyklos*. Vol. 57, No. 2, 173–196.

Chesney, T., Chuah, S.-H., and Hoffman, R. (2007). Virtual World Experimentation: An Exploratory Study. *Occasional Paper Series, No. 2007-21*. Nottingham University Business School. Online: http://ideas.repec.org/p/nub/occpap/21.html

Forsyth, F. G., and Fowler, R. F. (1981). The Theory and Practice of Chain Price Index Numbers, *Journal of the Royal Statistical Society,* Series A, Vol. 144, No. 2, 224–246. London: Royal Statistical Society.

Guðmundsson, E., and Halldórsson, K. Þ. (2008). *Quarterly Economic Newsletter*. 4th Quarter 2007, CCP Games. Online: http://ccp.vo.llnwd.net/o2/pdf/QEN_Q4-2007.pdf

HIIT (2007). Virtual economy research project starting at Helsinki Institute for Information Technology, *Helsinki Institute for Information Technology press release*, December 12. Online: http://www.virtual-economy.org/blog/hiit_starts_new_research_proje

Lehdonvirta, V. (2006). Interview With CCP: EVE Currency Traders 'Going to lose big'?, *Virtual Economy Research Network*, October 2. Online: http://virtual-economy.org/blog/interview_with_ccp_eve_currenc

Lehtiniemi, T. (2007). How Big Is the RMT Market Anyway?, *Virtual Economy Research Network*, March 2. Online: http://virtual-economy.org/blog/how_big_is_the_rmt_market_anyw

Lessig, L. (1999). *Code and Other Laws of Cyberspace,* New York: Basic Books.

Nicklisch, A., and Salz, T. (2008). Reciprocity and Status in a Virtual Field Experiment, *Preprints of the Max Planck Institute for Research on Collective Goods.* 2008/37, Bonn.

Ondrejka, C. (2004). *Aviators, Moguls, Fashionistas and Barons: Economics and Ownership in Second Life*. Linden Research. Online: http://ssrn.com/abstract=614663

Schwartz, A. J. (1975). Secular Price Changes in Historical Perspective, *Journal of Money, Credit and Banking*. Vol. 5, No. 1, 243–269. Ohio: State University Press.

Simpson, Z. B. (1999). The In-Game Economics of Ultima Online, *Computer Game Developer's Conference*, CA: San Jose, March 2000. Online: http://www.mine-control.com/zack/uoecon/uoecon.html

Stiglitz, J. E., and Driffill, J. (2000). *Economics.* New York: W. W. Norton & Company.

United Nations (2001). *United Nations System of National Accounts 1993 Internet access system.* Online: http://unstats.un.org/unsd/sna1993/introduction.asp

United Nations (2003). National Accounts: A Practical Introduction, *Studies in Methods*, Series F, No. 85, New York: UN Department of Economic and Social Affairs, Statistics Division.

Wynne, M. A., and Sigalla, F. D. (1994). The Consumer Price Index, *Economic Review – Second Quarter 1994*, Federal Reserve Bank of Dallas.

Yee, N. (2006). The Demographics, Motivations and Derived Experiences of the Users of Massively Multi-User Online Graphical Environments, *PRESENCE: Teleoperators and Virtual Environments*, No. 515, 309–329. MIT Press.