A Framework of Attention as a Medium of Exchange

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Abstract

Research in the economics of attention generally approaches attention as a scarce resource and the design of systems to efficiently allocate that resource. This paper approaches the topic with a slight twist. Instead of designing systems to allocate attention, we look to designing systems where attention is a medium of exchange. This does not advocate that attention isn't scarce, but, much like money, we can use attention to exchange for and allocate the goods that we really want (i.e. information goods). From this basic premise, this paper presents a conceptual framework and some insights into the nature of attention as a medium of exchange. The utility of the conceptual framework is derived from broad applicability, and this is accomplished in several ways. First, it adds coherence to an array of seemingly disparate research papers on the economics of attention. Second, existing systems currently using attention as medium of exchange can be described using the framework. More interestingly, though, the framework provides a common language to visualize new systems or augment existing systems. Lastly, the framework allows for decomposing systems in a way that is amenable to economic analysis. With that, we can compare the efficiency of differing systems or simply understand the implications and dynamics of a given system.

1 Introduction

Herbert Simon first observed the simple but fundamental connection between information and attention as stated here:
"What information consumes is rather obvious: it consumes the attention of its recipients. Hence a wealth of information creates a poverty of attention, and a need to allocate that attention efficiently among the overabundance of information sources that might consume it."
(Simon 1971).

Falkinger elaborates on the implications of the interplay of attention and information. Falkinger developed a theoretical model based on empirical research comparing information-rich and information-poor economies. Information-poor economies have enough attention to pay to all available information, while information-rich lack enough attention. Falkinger concludes that information-rich economies reach an inefficient equilibrium due to attention-seekers engaging in wasteful signaling in the competition for attention. In addition, Falkinger notes that there may be consequences for welfare in that the information attended to in information-rich economies are not guaranteed to be the optimal set of information (Falkinger 2005).

The information economics literature has also discussed in-depth a host of problems regarding information. Asymmetric information and incentives to hide information can lead to inefficient markets (Akerlof 2002). Inability to recoup initial high-costs of production of information may steer producers away from investing in the production of information (Shapiro, Varian 1999). If we put incentives to hide private information and costs of information production to the side, we might expect maximum efficiency could be achieved. Because information is non-rivalrous and has zero marginal reproduction and distribution cost, there is no need to ration an information good by price. Maximum efficiency can be achieved by distributing all information to everyone for free (Foray 2004). Unfortunately, information does still have a cost because the attention it consumes is finite, and efficiently allocating information is still problematic even in the most idealistic model. If we knew an individual's valuation of an item of information and the opportunity cost of attention, we could re-order all information with the highest to lowest profit (i.e. value - cost), and allow the user to consume information until attention is exhausted. Unfortunately, as mentioned beforehand, the value of an item of information is not determined until after consumption (Shapiro, Varian 1999).

There have been several proposed solutions to efficiently allocate information by designing systems that allocate attention as a valuable scarce resource. Designing systems using money to allocate attention appears to be an common-sense solution, but these solutions has been met with criticism. For instance, one system proposed charging money for email with the prospect of ameliorating spam, an attention-wasting activity (Loder, Alstyne, Wash 2006). Charging money for priority email has been confronted by public disapproval, and, subsequently interest has increased in designing systems where money transfers are not allowed. Hartline and Roughgarden explore systems designed to expend human computational resources solving a challenge as a substitute to money (Hartline, Roughgarden 2007). While social stigma and

technical difficulty are some barriers to using money for attention exchanges, Goldman also argues that bargaining between attention-seekers and consumers consumes the very thing we wish to conserve (Goldman 2005). We extend on this observation asserting that systems requiring the continual management and establishment of contracts of future attention could in some cases be more costly than the attention conserved.

1.1 Problem Statement

Efficiently allocating information is problematic. Consuming information simultaneously consumes attention, and information-rich environments do not have enough attention to consume all available information. In addition, an individual does not know the value of information until after consumption, and, thus, it is difficult to guarantee that the information consumed under constraints of limited attention is the utility-maximizing set of information.

1.2 Motivation

This research aims to propose an alternative view to designing systems using attention. Instead of designing systems that allocate attention as scarce resource, we consider a twist on the idea, to design systems using attention as medium of exchange to allocate information.

While some systems, such as the scientific economy and advertising, have already been identified as using attention as a medium of exchange (Franck 2002)(Bagozzi 1975), we currently lack a framework to understanding these types of systems. A framework will guide us in understanding how those systems work using attention as a medium of exchange as well as give us insight into conceiving and designing new systems. We are asserting that the concept of attention as a medium exchange is fundamental and exists exclusive to the system it is embedded in. Therefore, we need to understand the properties, limitations, assumptions, and benefits of attention as medium of exchange before we can start addressing specific contextual questions.

One reason for this approach is because attention has special characteristics that are distinct from typical resources but are common in mediums of exchange. Most fundamentally, despite proponents arguing that attention is highly valuable (Lanham 2006)(Davenport, Beck 2001)(Goldhaber 1997)(Huberman 2006), attention, much like money, has no inherent value. The assumption that attention has immense value inhibits us from pursuing effective designs of systems. For instance, we might labor under the guise that conservation of attention is valuable (Goldman 2005), attention-seeking behavior is an end in of itself, or that the value of attention can be measured (Davenport, Beck 2001). In addition, the finiteness of attention as a medium of exchange is less concerning because systems are designed such that attention acts as a signal of the scarcity and value of the information goods it pays for. The most salient reason to approach the design of systems using attention as a medium of exchange is because in some cases it increases the efficient allocation of information.

1.3 Paper Outline

The rest of this paper is presented as follows. In Section 2: Literature Review we discuss previous work on attention used a medium of exchange, an introduction to the framework, and relevant literature unifying seemingly disparate literature. In Section 3: Framework we detail the framework, assumptions, and limitations. In The Section 4: Framework Applications section we validate the proposed model by devising scenarios in which the model can enhance our understanding of attention as medium of exchange. In Section 5 we conclude, and in Section 6: Future Work we highlight potential avenues for future research.

2 Literature Review

2.1 Previous Work

While it may sound unorthodox, using attention as a medium of exchange is not quite a novel concept. Goldhaber is typically credited as being the first to recognize that attention can be used as a medium of exchange. Goldhaber envisions the economy of the future will solely exist on attention as the dominant and accepted medium of exchange. Material goods, along with conventional money, will become less relevant—simply an artifact of the industrial age (Goldhaber 1997). Lanham, in "The Economics of Attention", also has a similar complementary vision. Again, material goods will become less relevant while the information related to the material good will become more relevant (Lanham 2006). In both views, successful participants in the market survive by the amount of attention attracted. In Goldhaber's view, the motivation to attract attention, or be a star, is the potential to induce a fan, those who pay attention to the star, to take actions preferable to the star. In other words, a fan can be motivated by the star to fulfill the preferences of the star (Goldhaber 1997). For instance, let's suppose I want to pay all of my attention to Beyonce Knowles. Paying attention to Beyonce means that I learn her preferences, and if I didn't care about Beyonce's preferences, I have plenty of alternative ways to spend my attention. Because I've invested attention and want to see her preferences attained, when she's thirsty I am motivated to bring her a bottle of water. Another example is when a presenter has a captive audience paying attention. If the presenter asks the audience to raise their hands, they certainly will because the audience is briefly interested in fulfilling the preferences of the presenter. Yet another example is when I am reading the New York Times. They briefly have control of where I pay attention, and they can motivate me to pay attention to an advertisement.

Goldhaber's vision is interesting and has some concepts worth merit. On the other hand, Goldhaber also argues that neoclassical economics cannot at all explain the attention economy. Neoclassical economics was designed for the industrial economy and lends no insight into using attention as a medium of exchange (Goldhaber 1997). Goldhaber has crafted his arguments such that we cannot research the economics of attention without completely disregarding and rebuilding economic theory. Therefore, while his intuition is somewhat useful, we are lost as to how to approach the attention economy other than accepting it as inevitable. This simply is not

true. Fortunately, Ghosh retorts to Goldhaber's assertions by stating that many of his concepts can be successfully mapped to economic principles. For instance, Goldhaber claims that an attention economy will result in perpetual novelty and creativity. Ghosh points out that this is because information, what attention is exchanged for, has high diminishing returns, and, therefore it is not surprising that novelty ensues (Ghosh 1997). In addition, Franck gives us an actual concrete economic description of a system that currently exists using attention as a medium of exchange—the scientific economy. As Franck explains, scientists behave as economically rational profit-maximizing individuals. Instead of maximizing money earned, scientists are motivated by fame and vanity to maximize attention attracted. The citation is a simple attention accounting system allowing this economy to prosper. In order for a scientist to attract attention, s/he must produce research worthy of attention. S/he will be motivated to provide the research for free as a capital input given authorship is cited, and being cited increases the probability of attracting attention. In addition, a scientist is also motivated to spend his/her attention wisely because inefficient allocation of one's own attention results in finding less valuable capital inputs, producing less valuable publications, and, thus, attracting less attention (Franck 2002).

Bagozzi, in "Marketing as Exchange", describes another system, advertising, which uses attention as a medium of exchange. Exchange for intangibles, such as entertainment, was highly debated in Marketing literature in the early 1970s, but is now quite obviously accepted as a valid form of exchange. Bagozzi argues the role of Marketing is a facilitator of complex exchanges. In other words, complex systems of exchange can be more than a consumer/producer relationship. For instance, an individual exchanges attention for television entertainment, s/he sees an advertisement for a book, the advertisement was placed by the network, the advertisement was created by an agency, the agency was hired by the book publisher, and, ideally, the individual buys the book from the publisher (Bagozzi 1975). While Bagozzi does not specifically single out attention as critical in marketing exchanges, he acknowledges the use of attention as valid medium of exchange enabling some complex systems of exchange to exist.

2.2 An Introduction to the Framework

The framework consists of three elements:

Attention as medium of exchange
Attention has no inherent value. It is preferable to always exchange attention for information, and, thus, conservation of attention is never preferred. In addition, one seeks attention in order to exchange information. All information is freely disposable, and negative utilities are the result of expected opportunity costs. What an individual pays attention to reveals his/her belief of expected opportunity costs and expected value.

Information and attention are organized into streams
Attention is continuously being exchanged. Treating attention as a stream is intuitive, and, thus, analyzing information as a stream is appropriate. While we cannot know the value of information

until it has been consumed, an information stream allows an individual to make expectations of the value of future items in a given stream. In addition, where attention flows also indicates that information must be flowing in the opposite direction.

Systems can be decomposed into operational components of attention-based mechanisms
Building on the previous elements, systems can be designed using conceptual components that augment the exchange of information and attention. Components detail operations that will be performed when information/attentions stream are input into the component resulting in a augmented attention/information stream output. From this, we can rearrange systems, devise new systems, or conduct economic analysis.

2.3 Unifying Disparate Literature Using the Framework

Goldhaber's, Franck's, and Bagozzi's work all share a common underlying theme. Market participants, whether stars, researchers, or advertisers, are seeking attention in exchange for a stream of information they are outputting. Attention-seekers do not value attention; they value market participants exchanging attention for the information stream they are outputting. They value this because it might influence information consumers to engage in actions that are beneficial to the attention-seekers. Acquiring attention may mean increased sales for the advertiser. As Falkinger described, competition for attention is a prerequisite for any economic exchange to occur (Falkinger). Acquiring attention may mean increased citations for researchers, and more citations may mean better job offers, more opportunities to conduct cutting-edge research, or more influence on the direction of science. Similarly, Loder, Van Alstyne, and Wash reveal insight into the motivation of spammers; attention exchanged for information increases the probability that some (albeit probably few) individuals will buy what the spammer is offering.

In most cases, although imperfect, attention paid has potential for signaling the value of a producer's information stream compared to alternatives. Advertising-supported websites that can keep attracting future investments of attention are probably outputting a highly-valued information stream. Researchers that can keep attracting future investments of attention and citations are probably outputting a highly-valuable information stream. In other cases like spam, the design of the system obscures the value of the spammer's information stream. In other words, market participants are induced to pay attention resulting in a negative utility because there is no discernible information stream to make expectations of value about.

The cost of consuming an information stream isn't that attention is consumed but that there is an opportunity cost to consume something else. One may dislike spam not so much because of it in itself but because one knows the expected opportunity cost is higher than the value of the spam. Marketing literature covers information and attention streams opportunity costs from many perspectives. Janiszewski presents a competition for attention theory where attention allocated to information is impacted by surrounding visual elements (Janiszewski 1998). Wang and Day present the concept of a "meaningful path" where an individual's willingness to pay attention depends on how far along the information seeking experience s/he is. If the individual has just

started exploring information, s/he is more willing to pay attention to a variety of items. If the individual is far along on the path, s/he is less willing to pay attention to contextual items (Wang, Day 2007). For instance, a user will be willing to pay attention to many items on a website homepage, but once the user reaches a webpage deep within the site, s/he will only want to pay attention to the main content. Rosbergen, Pieters, Wedel demonstrate that individuals in different market segments pay attention to different visual elements in advertisement (Rosenbergen, Pieters, Wedel 1997). In these cases, consumers are making expectations of where to flow their own attention stream, and attention-seekers are making expectations on where or how to exchange their own information stream for the consumer's attention stream.

What stands in-between the consumers and attention-seekers are various entities that alter the attention and information streams. We consider these entities as attention exchange components of a system. These components do not necessarily have to be technological; an individual could be an attention exchange component. A researcher, while seeking attention, also alters the attention stream received to previous research via citations. An advertising-supported internet business distributes an attention stream across his/her own information and advertising. To ameliorate spam and "intrusive" marketing, Goldman proposes a personal device, a relevancy filter, that learns a consumer's preferences and filters/sorts all incoming information (Goldman 2005). This is attention exchange component that alters the flow of attention and information streams. Huberman and Wu proposed an algorithm to maximize the value of a consumer's attention using a dual restless bandit algorithm. In this research, consumers are presented with a list of items, such as in search results, so large that attention is exhausted well before reaching the end of the list. The issue Huberman and Wu explore is that items at the top receive increasing returns of attention not solely attributed to the value of the item (Huberman, Wu 2006). Again, this algorithm is an attention exchange component. Lastly, if we refer back to Bagozzi's notion of marketing as a facilitator and creator of complex exchange systems, we can envision that complex exchange systems could be composed of a variety of attention exchange components.

3 Framework

3.1 Attention as Medium of Exchange

3.1.1 Characteristics of Attention

While some characteristics of attention are what would expect from a medium of exchange, there are others that are very unique. We can characterize attention and mediums of exchange as follows:

Attention	**Mediums of Exchange**
Is finite	Is finite
Has no inherent value	Has no inherent value
Is divisible	Is divisible
Is fungible	Is fungible
Is not durable	Is durable
Is not transferable	Is transferable
Is persistent (i.e. we will always have some of it in the future)	Is not persistent (i.e. we potentially could not have some of it in the future)
Is equitable (i.e. we have equal amount)	Is not equitable (i.e. we potentially may not have equal shares)

(Descriptions of mediums of exchange adapted from Ludwig Von Mises's "The Theory of Money and Credit")

Attention is finite
Psychological literature describes attention as a gradient where an individual can simultaneously be aware of his or her environment while being focused on one particular item. The items focused on are being processed by more intensive cognitive functions of the brain. Items out of focus are being processed by lower level functions of the brain (Kahneman 1973). For instance, if an individual were driving, s/he is paying little attention to most of the tasks because those tasks have become routinized functions of the brain. On the other hand, when another individual swerves right in front, s/he will suddenly become acutely aware of every event happening. Despite how marvelous the brain is at allocating and routinizing incoming information, there is a limit to how much information can be input at any given moment. Psychological literature tends to focus at the individual level, but economic analysis would focus on the interaction of many individuals. Because attention is finite at the individual level, it is also finite at the aggregate level, and we can justify that it is appropriate to address as an economic issue.

Attention has no inherent value.
An individual consumes information from his/her environment. This may be in typical ways such as reading an online article or just noticing that the chair in your room hasn't moved. In either case, the individual consumes information from the environment and makes decisions. We assume information is freely disposable; more information is preferred to less. In other words, one always prefers to exchange attention for information, and attention, the potential to consumer information, has no inherent value.

Attention is divisible
Attention can be considered divisible. While it's not realistic to say that one could spend exactly 2.35 units of attention on some task, we can choose to spend little or a great deal of attention on a task (or something in-between). Divisibility in mediums of exchange are important such that dividing the medium in finer amounts does not destroy it. On other hand, this is not a concern with attention; it will continually be destroyed no matter what happens.

Attention is fungible
It may appear that attention from some individuals is more valuable than others. If we refer back to the premise that attention has no inherent value, then we can conclude that all attention is indistinguishable. Different valuations of attention is a misappropriated concept; we value the *exchanges* differently.

The afore-mentioned characteristics of attention are similar to characteristics that we expect from typical mediums of exchange. The following are characteristics are distinct from typical mediums of exchange.

Attention is not durable nor transferable
If attention were durable, we could save moments of attention in order to consume a very large amount of information in a given period. If attention were transferable, one could give his/her attention to someone else to accomplish the same goal. We can't do this with attention. Once attention is paid, it is gone forever, and this happens continuously.

Attention is persistent
While one can only pay a finite amount in a given time period, there is always a next future time period where one will have attention to pay.

Attention is equitable
Every individual can consume roughly the same amount of information in a given time period. Lack of transferability and durability inhibits unequal amounts of attention. While this is an especially interesting characteristic of attention, it is outside the scope of this research and is allocated for future work.

These unique characteristics do not pose an issue for using attention as a medium of exchange. In some cases, systems have to be designed differently. In other cases, the differing characteristics allot for previously unrealizable designs.

3.1.2 Characteristics of attention as a medium of exchange

It may seem counter-intuitive, especially considering proponents arguing that attention is highly valuable, attention has no inherent value. Attention can only be *exchanged* for information, and more information is assumed to be preferable. By information, we are not simply referring to documents or webpages, but *any* information about the environment the individual is in. For instance, let's suppose an individual where placed in a elaborate deprivation chamber that restricts all access to any information. Certainly, the *potential* to acquire information in an information-less environment is of no value. Even if at some later point the individual were released, the forgone attention is still of no value; that attention is gone forever. Because any information is valuable and attention constitutes only the potential to acquire information, exchanging attention for information is always preferred. This is similar to conventional money. There is little value derived from possessing money itself; the value is derived from what can be exchanged with money.

Following is a model and implications of attention as finite.

Let T be an array of integers indexing time periods with range [0, ∞].

Let m be an integer with range [0, ∞] represent the number of items of information that can be consumed in one time period by an individual. For simplicity of the model, we assume that every individual has the same m. The cost of m is an opportunity cost, the next highest valued item that could have been consumed.

Let n be an integer with range [0, ∞] represent the number of items of information that can be produced in one time period by an individual. For simplicity of the model, we assume that every individual has the same n. The cost of n is an opportunity cost, the next highest valued item that could have been produced.

Attention is m, the number items an individual can consume in a given time period.

We analyze the model using a thought experiment. In a monetary economy, money and, thus, the market prices that emerge are signals of the scarcity of resources (Hayek 1945). Signals allow us to allocate resources in a decentralized manner. Because resources are scarce, mis-allocation is undesirable and inefficient. If a typical resource is infinite, we simply do not need a signal indicating the scarcity of that resource. For instance, air, while not technically infinite, is plentiful enough that we simply do not need to ensure proper allocation of it as a resource. Thus, we would not trade air using money. On the other hand, we can imagine that if pollution were to become a serious problem, we might begin to institutionalize the trade of air using money. If money, on the other hand, were to be set to an infinite supply, mis-allocation of resources would become imminent. This is to say, an infinite supply of money would fail to provide signals on the scarcity of resources. In addition, if money were non-existent, substantial friction would squelch trade that would have occurred. So, by the nature of money being a proxy of the value and scarcity of goods, necessarily has to be finite. Other goods we would desire to be infinite.

We apply this logic to attention. Let us set m=0. In this scenario all market participants simply cannot consume any information. This is obviously a terrible condition; no market participant has any information and cannot make effective decisions. More interestingly, though, is when we set m=∞. In this scenario, a market participant can in one time period consume all available information (again, assuming that hidden information and action is not relevant here).

If information is inherently valuable, and more information is better than less, we might expect that this would be the optimal outcome. Let us not forget the producers of information. In this context, producers still face an opportunity cost for the production of information in a given T where n is less than ∞. While quite thought-provoking, we disregard the scenario of a producer producing an infinite amount of information in a given time period as completely unrealistic and not worth entertaining. Each bundle that could have been produced will undoubtedly lead to better or worse market outcomes. For each bundle, a producer faces an opportunity cost from the next best bundle that could have been produced in T. If attention is infinite, then *any* bundle produced will always be consumed, and any signals that payment of attention could have provided will cease to exist. Producers might as well randomly select anything to produce with complete disregard of market outcomes that different bundles will create.

Attention is not infinite, and, like money, we are better off because it acts as a proxy of value and scarcity of information guiding consumers and producers to pursue the most appropriate information in given time period.

3.2 Attention and Information as Streams

An individual is in a constant state of paying attention. It may be tempting to quantify attention, but Davenport describes that the nature of attention lends itself to imprecise measurements (Davenport, Beck 2001). It's more intuitive to assume attention is a stream, and in conjunction, it is also appropriate to treat information as a stream as well. Goldhaber supports this by describing that where attention flows, information necessarily has to flow in the opposite direction (Goldhaber 1997).

While an individual may not know the value of information until after consumption, we can approach this issue by changing perspective slightly considering information as also a stream. This is to say that there is not just a cloud filled with items of information that individuals pick from, but items of information can be arranged in an order with previous and future items. Past items reduce uncertainty by providing expectations of value of future items. Some arrangements will essentially look random in that past items are not informative of future items. On the other hand, if the items could magically be arranged from highest value to lowest value, and the individual traversing this list knows that, s/he could make an expectation about whether to consume the next item in the information stream.

There is also evidence of individual expectations of the informativeness of future information. Gabaix, Laibson, Moloche, Weinberg arranged an behavioral experiment in which the variance of values in given stream decreased. Gabaix, Laibson, Moloche actually referred to streams as product attributes arranged from left to right, and the user revealed each value left to right while having the option to switch to other products for investigation. The experiment involved individuals making decisions on whether to reveal values in a matrix of options where rows represented different products while columns represented different attributes of the products. The boxes contained negative and positive values, and the participants knew that the values decreased in variance from left to right (i.e. the product attributes). It was discovered that individuals predictably, using options-value analysis, attempt to maximize utility by switching to streams that were more informative (i.e. higher variance of values) (Gabaix, Laibson, Moloche, Weinberg 2003).

Given information and attention are arranged in streams, we can reveal the implications of such a model. Let's suppose that Person A consumes a raw stream of information as an input, and s/he can output the stream of information to Person B. Person A can mix his/her attention and modify the stream. For instance, s/he may mark items as "interesting" and items as "not interesting". Simply, the information stream and attention stream have been reorganized. For instance, interesting items are pushed to the top while uninteresting items are pushed to the bottom. Person B will take Person A's stream as input if s/he values the modified stream more than the original raw stream. If this was not the case, Person B would prefer to consume the raw information stream because it is of higher value.

We might expect that having Person A mix attention and provide an input to Person B is preferable to having both consume the raw stream itself. This is because both individuals consuming the raw stream wastes attention that could have been put to higher valued uses. In other words, excess attention is being paid with no discernible advantage. For instance, The New York Times pays attention to and consumes raw information of all the daily events happening in the world. They mix their attention by deciding what items are or are not newsworthy, and they output that as a stream of information (i.e. a daily newspaper). For me, the information stream output by the New York Times is more valuable than consuming the raw information stream. This is to say, I'd rather read the paper than be a journalist. If I did not prefer this situation, I would simply become a journalist and devote my attention to the world daily events. In addition, as a consumer, because I can make more accurate predictions of the value of the next items in the stream (i.e. the daily paper), I can make more accurate expectations of where to devote my attention. In other words, the New York Times will devote a substantial amount of attention to daily world events because the raw stream is more than likely random looking. On the other hand, I can peruse a couple of sections of the paper and make the prediction that there is not anything more of value for today. I can move on to other things for the rest of the day.

Person A is not going to expend effort to the benefit of Person B without some realizable benefit of doing so, and, given that, we might expect that Person A will simply hide his/her stream so that no individual can access it. The benefit Person A realizes is increased certainty of future attention paid to future items of information in his/her output stream. For instance, Person B is presented with the situation where the last three and only items in Person A's stream were of high

value, therefore, according to Person B there is a high probability that the next item in the stream is of high value. With this type of logic we can then estimate the value of an item that could be output by Person A at which Person B is indifferent from continuing to consume or abandoning Person A's information stream. This is to say that one negative valued item in of itself may not induce Person B to discontinue consuming the stream of information. We now have a concrete description similar to Goldhaber's concept of an attention economy. Person A has some limited influence over what Person B will pay attention to based on past performance of Person A's information stream.

To elaborate, let's consider Person A has two options in a strategy space, output items highly valued by Person B (S1) or output items with low value where the opportunity cost is equal to zero (S2). In S2, if Person B consumes one item of information with a negative value then s/he will abandon. In other words, the expected value of the next item in the information stream is lower than the expected opportunity cost. On the other hand, in S1, if Person B consumes an item of information with a negative value s/he may still continue to consume the stream. In other words, the expected value of the next item in the stream could still be higher than the expected opportunity cost. This means that output of lots of high valued items allots Person A a range of item values that s/he can induce person B to consume. We can consider this range is what constitutes an attention currency. It's the attention that will certainly be paid for valuable output.

For instance, while I enjoy episodes of "A Shot at Love with Tila Tequila", the value of the episodes barely cover the opportunity cost of attention paid. It would take one bad episode for me to completely abandon the show. On the other hand, the first three Star Wars movies were of such high value that I was willing to endure three extremely terrible episodes. The point is that I simply did not abandon the Star Wars movies after experiencing one negative valued item in the stream. Another obvious example of this principle is in our previous example, the New York Times. In this case, advertisements are low-valued items for most individuals. If the New York Times outputs a highly valuable stream, then they can insert advertisements. On the other hand, if the New York Times outputs a low-valued stream, inserting advertisements would induce most consumers to abandon the stream.

3.3 Operational Components for Attention-based Mechanisms

If we refer back to the information and attention as stream portion of the framework, we will notice an interesting dynamic emerge. There is a consumer, raw information, and an intermediary that stands in between the consumer and raw information. The intermediary is performing an operation on the raw information stream as well as the stream of attention being input into the intermediary. This operation alters the exchange of attention and information in a system. The intermediary is a component of a system, operating on any information/attention stream that is inputted. The afore-mentioned operation (e.g. "it's interesting", "it's not interesting") is only one example of the types of operations that could be performed.

Based on observation, we've compiled a list of components and examples that we believe to exist. This list is certainly not comprehensive.

Attention for Information Exchanger
A primitive component of attention. Exchanges attention for information.

Examples: There are a plethora examples of this component. Websites, Email clients, Television, Documents, Phones, Tradeshows are a few.

Attention to Conventional Money Converter
Future surplus attention paid to information producer can be sold to attention-seekers.

Examples: Most advertising or sponsored based business models use this component. A producer of information earning surplus attention can direct and exchange surplus attention for money from attention-seekers. For instance, Google, Facebook, Yahoo, television stations, radio, magazines (a few of countless others) all sell a portion of future attention to others. There are other alternatives. Email distribution lists, the opportunity to gain attention from others, is an example of future attention exchanged for money. In addition, recorded attention (or behaviors that reveal how attention is spent) can be exchanged for money. For instance, Facebook Beacon, Microsoft AdCenter and Google AdSense are all examples of selling recorded behavior. While recorded attention is not in of itself useful, it informs attention-seekers where the best opportunities for gaining attention are. Lastly, Amazon offers a unique model where information producers can choose to link to Amazon. If a consumer follows the link and purchases the item, the producer receives a percentage of the sale.

Attention to Signal Converter
Requires agent to waste attention to produce a signal.

Examples: Captchas or lengthy forms are ways to screen out a population of agents. In other words, those willing to pay more attention have higher valuations of the information hidden behind these mechanisms. For instance, online forms to gain access to white papers can screen out low-quality leads. A file-sharing service www.rapidshare.com asks users to wait for several seconds in order to download a file (the user can also pay for a membership in order to avoid the wasted attention). Entering a query in Google is signal that an agent will pay future attention to the results. While it may be somewhat weak it does requires some attention.

Attention Allocater
An agent cannot simultaneously pay attention to an entire information stream. A stream can be represented in a single dimension (a queue) or a more complex higher-dimensional structures that allocates attention.

Examples: Numerous websites list items (products, search results, documents). Generally, an agent will pay attention to the first item in a list, then the second, and so on. More complex ways to allocate attention involve x-y positioning, color, size, contrast, and gestalt principles. Typically, these complex techniques are quite common to graphic designers.

Attention Reallocater
Requires attention allocater. Reallocates attention based on a set of parameters.

Examples: Google constantly reallocates search results for specific keyword based on the changing information found on the internet. Amazon reallocates attention to products based on past agent-behavior as well as similar agents. Simply sorting features found in Excel or on any E-commerce site reallocates attention based on an agent signal. More interestingly, a paper called "Organic Information Design" outlines an agent-based system that adapts information according to typical afore-mentioned graphic design techniques (Fry 1997).

Attention Stealer
A most disturbing component in that seemingly violates individual autonomy without much protection. It steals an agent's attention, but this does not necessarily imply negative utility to agent.

Examples: If my phone rings, it steals my attention because I did not express consent to pay attention. If it is a telemarketer, I most likely will be irritated. If it's my grandmother I most likely will be happy. Pop-up ads, ads that shake behind my browser, as well as Microsoft's Clippy are all examples of the "Attention Stealer" components. If someone says my name in a crowd, that person steals my attention (even if unintentionally).

Attention Inferences Recorder
Recording attention might be difficult, but we can record actions that infer amount of and value gained from attention paid. For instance, an ad that was clicked on was probably paid attention. On the other hand, "I agree" in a EULA may fail to correlate well with whether or not an agent paid attention.

Examples: Google analytics, Omniture, Feedburner, Doubleclick are all companies that record online agent behavior. From this wealth of data, what was paid attention, and the value derived can be teased out of the numbers.

Attention Tester
Test whether or not agent paid attention to information stream.

Examples: For instance, a url placed only in source code of HTML doc (i.e. an easter egg) when accessed tests whether one paid attention to the HTML source code. Another simple example of testing attention are school exams. LinkedIn constantly send network updates to consumers. If they are truly interested in the contacts, they won't mind spending attention on the updates. On the other hand, if an agent is willing to connect with anyone, these updates will waste attention. This system test whether individuals really want to pay attention.

Information Stream based on Synchronous Attention Instantiater
Information stream is instantiated only when 2 or more agents simultaneously pay attention to each other.

Examples: Rock band (a video game) offers a game where two-players can play against each other. The information stream (the game) doesn't exist unless both are willing to pay attention to each other. In fact, if one player drops out before the end, the game quickly ceases to be worth paying attention to.

Information Stream based on Asynchronous Attention Instantiater
Information stream is created when two agents take turns exchanging attention for information.

Examples: For instance, an email conversation or phone conversation is an example of asynchronous attention.

Information Stream based on signal Instantiater
Requires attention to signal converter. Information stream is created based on signal that future attention will be paid.

Examples: For instance, entering a search engine query signals that agent will pay attention to instantiated information stream.

Attention Limiter
Amount of attention payment is limited.

Examples: For instance, Google ads do not allow any attention-getting treatment, effectively limiting the amount of attention an ad can command, and, thus, reducing wasteful competition of attention.

Attention Restricter
Attention cannot be paid by agent unless agent performs specified action(s).

Examples: For instance, video games tend to use this component. One cannot pay attention to some portions of the game until previous levels have been completed. In a different scenario, one cannot pay attention to someone's network updates in LinkedIn.com until s/he gets permission from the individual.

Attention Funneler
An information stream that is progressively accessed via attention restricters. In other words, the n^{th} item in the stream cannot be accessed unless (n-1) was accessed prior.

Examples: This is common technique in marketing. An organization creates a funnel in order to reveal consumer valuations of a product based on successive amounts of attention paid. In other words, those who drop off quickly have low valuations, and those who keep paying attention are probably more interested.

Attention Across Streams Distributer
This component mixes two or more information streams. Agent pays attention to a mix of streams.

Examples: This component is quite widespread. The advertising-supported model is an example where one stream (a magazine, search results, television show) is mixed with another stream (the market of available advertising). The consumer may not be forced to pay attention to the advertising, but the advertising stream does consume "some" attention. Another example is the scientific economy where a published paper (one stream of information) is mixed with citations (another stream).

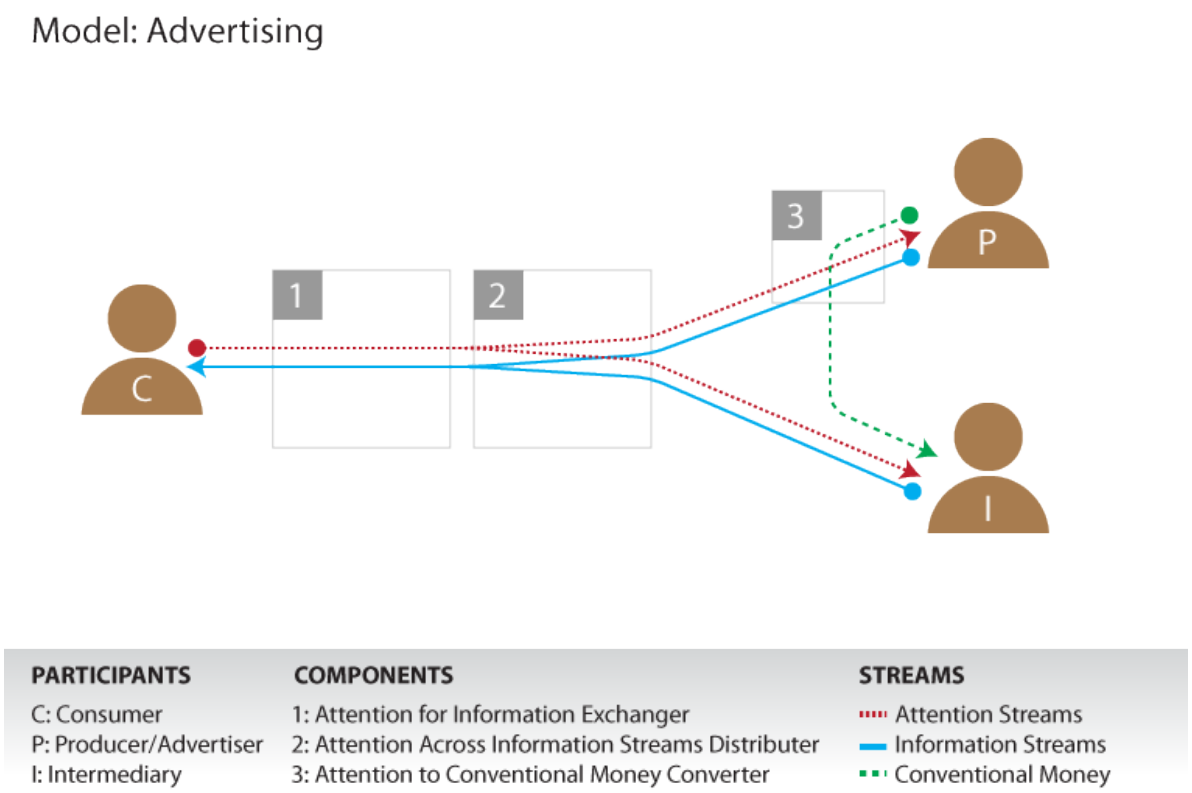
With operational components we can visualize how exchange of attention for information is flowing through a system. An existing system can be decomposed into components and efficiency analyzed. In addition, we can compare alternative system designs as well as easily conceive of new systems.

4 Framework Applications

To demonstrate the validity of the framework, we apply it to several existing and new systems. First, we analyze the two existing systems using attention as a medium of exchange discussed in literature, advertising and the scientific economy. For these systems we primarily explore the "Attention Across Streams Distributor" component.

4.1 Analyzing existing systems using attention as medium of exchange

4.1.1 Model: Advertising



In this model, we have three market participants, the market of consumers, the intermediary, and the market of producers (i.e. advertiser). The model uses the "Attention Across Streams Distributor" as well as "Attention to Conventional Money Converter". The producer values the consumer paying attention to the advertisement and will pay money for attention. The producer doesn't necessarily value the attention. S/he values the consumer exchanging attention for

information from the advertising. We can characterize this as the probability of the consumer taking an action desirable to the producer (e.g. buying a product) increases if the consumer consumes the producer's advertisement. For instance, letting consumers know that you have a product will increase the chance they buy the product. To induce the consumer to consume the advertisement information, the producer must also induce the consumer to pay attention.

In this case, we assume that the average value to the consumer of the market of advertisements is lower than the consumer's opportunity cost. This is reasonable. If not, we might expect to see more television programs and websites dedicated to only advertisements. The intermediary produces a stream of information as well. The average value of the intermediary's stream is higher than the consumer's opportunity cost. This means that the consumer will pay attention to the intermediary. The intermediary can operationally alter the consumer's paid attention by distributing it across his/her own stream and the stream of advertisements. The intermediary can choose the price and what percentage of his/her the stream to allocate to advertising.

The model is as follows:

q is a number from [0, 1] representing the portion that the intermediary allocates to advertising.
v represents the producer's value of getting attention.
p represents the price the intermediary charges the advertiser for access to his/her stream.

The intermediary's utility function:
$U_i = p*q;$

The advertiser's utility function:
$U_p = v*q*(1-q) - p*q;$

The advertiser has a value per quantity of the intermediary's stream. The consumer's opportunity costs are heterogeneous (represented by 1-q), and decreases in proportion to increases in advertising. In other words, if the intermediary's stream was allocated all to advertising, the market would not pay any attention. If the intermediary allocated nothing to advertising, the entire market would pay attention. The producer also loses utility due to having to pay a price for getting advertising space.

$\text{Max } U_p(q) = v*q*(1-q) - p*q - c;$
$\text{Max } U_p(q) = vq - vq^2 - pq - c;$

$U'_p(q) = v - 2vq - p = 0;$
$v(1-2q) = p;$
$1-2q = p/v;$
$2q = 1 - (p/v);$
$q = (1-(p/v))/2;$
$q = (1/2) - (p/2v);$

q=0 when p=v. If the intermediary charges a price equal to the value to the producer, then the

producer will want none of the intermediary's stream.

q increases as v increases, and q decreases as v decreases. The producer will want more of the stream if she/he gains more value from the stream.
q increases as p decreases, and q decreases as p increases. Not surprising, if the intermediary charges more, the producer demands less.

We now input the producer's demand equation into the intermediary's utility to determine the maximum price charged.
$U_i = p*q;$
$\text{Max } U_i(p) = p*(1/2 - (p/2v));$
$(1/2)p - (p^2 / 2v);$

$U'_i(p) = (1/2) - (1/2v)*2p = 0;$
$(1/2) - (2p/2v) = 0;$
$p=v/2;$

Not a surprise, if v increases p increases (and vice versa).

Let's put the price back into the producer's utility function.

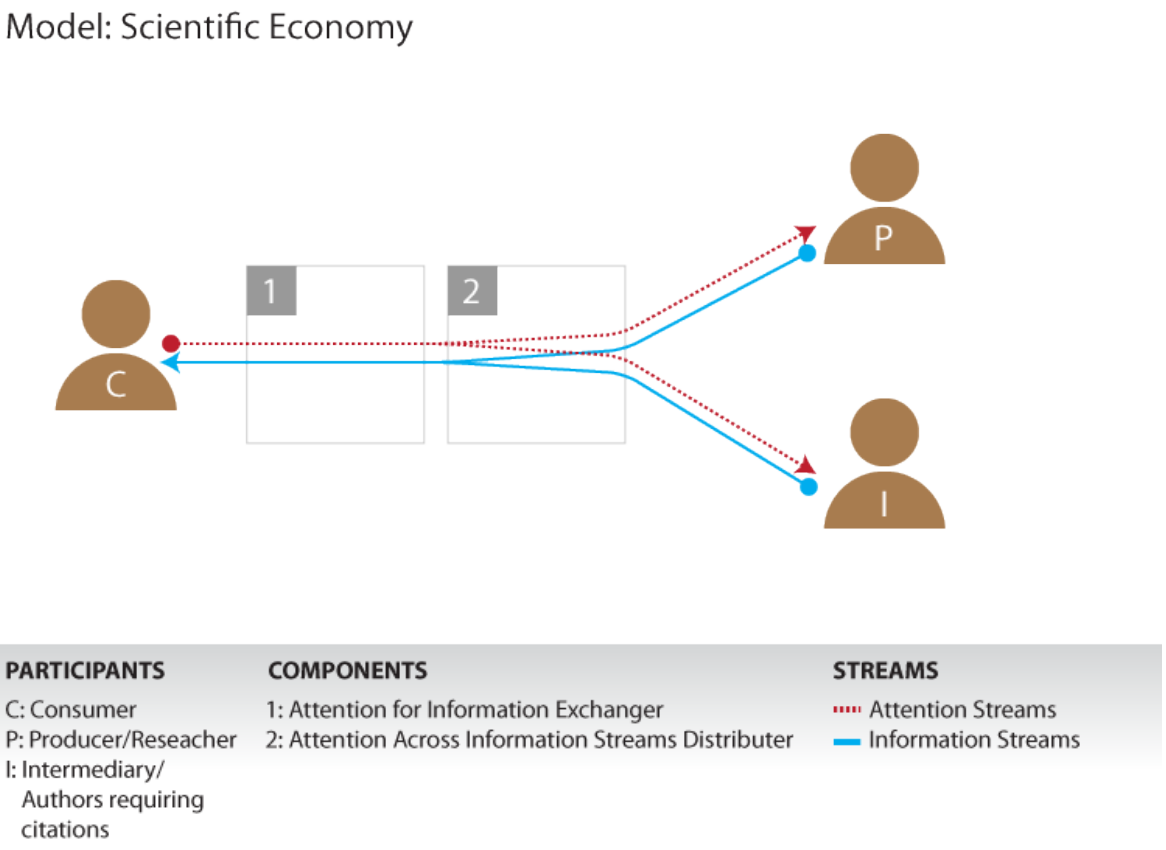
$q = (1/2) - (p/2v);$ rewritten as:
$q = (1/2) - (v/2)/(2v);$
$q = (1/2) - (1/4);$
$q = 1/4;$

Producer will demand 1/4 of stream given that the intermediary will maximize profits.

If we look to Google search results, this seems like a reasonable prediction. If consumers consume on average 32 results in a sitting, and Google sells 8 of those results to advertising, then 8/32 is 1/4 of the stream.

In addition, if the intermediary could not use attention as a medium of exchange, the entire system would disappear. The intermediary would gain no utility and his/her opportunity cost will certainly be higher than zero. S/he would exit the market. Without the intermediary, the consumers would cease to pay attention to advertisements. The producers would find it difficult to inform consumers of new and useful products.

4.1.2 Model: The Scientific Economy



Franck describes attention is what the researcher is trying to maximize and adding citations increases the amount attention the market will pay to a paper. This may seem different than the advertising case in that a secondary stream (i.e. the citations) increase the value of the stream, but, in fact, the researcher is the participant analogous to the advertiser. In other words, the researcher wants to mix his/her information stream with citations because it will increase the value. The citations are the higher valued stream. Franck describes that the value increases because the researcher is synthesizing valuable capital inputs. In an effort not to trend towards a model discussing synthesis of knowledge, we consider that citations increase value for consumers because it reduces the uncertainty of the research. In this model, we have two participants, the market of consumers and the researcher acting as both intermediary and producer. Franck also discusses that a researcher will have incentives to spend his/her attention wisely in order to amass the highest valued capital inputs (i.e. citations). In this model, we assume the researcher has acquired citations and there is already an average value for those

citations. In other words, the researcher has already done the best s/he could do to acquire knowledge and citations.

The model is as follows:

U_p is the utility of the researcher acting as producer and intermediary (referred to as producer from here out).
v is the value the producer places of attention paid by the consumers.
q is a number from [0, 1] representing the portion that the producer allocates to citations.

The producer's utility function is:
$U_p = v*q*(1-q) - v(1-q);$

The producer gains value from attention paid, but the market share decreases proportionally as the producer decreases allocation to citations. In other words, the market of consumers will pay no attention if there are no citations, and alternatively, the entire market of consumers will pay attention if the paper was all citations (represented by 1-q). That may seem odd, but on reflection, a paper devoted to a list of citations might be worth paying attention to. In addition, the researcher receives negative from forgone attention being allocated to citations (represented by v(1-q)).

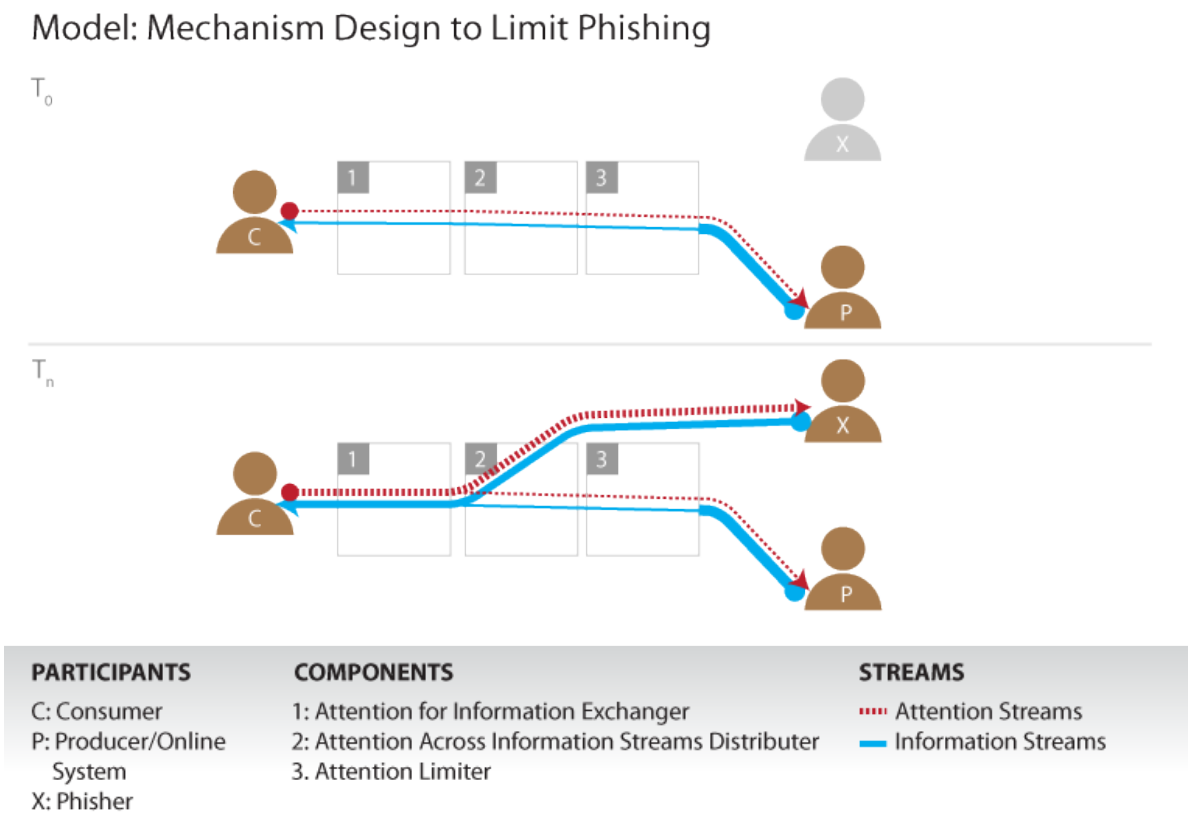
$\text{Max } U_p(q) = vq - vq^2 - v + vq$
$= 2vq - vq^2 - v;$

$U'_p(q) = 2v - 2vq - 1 = 0;$
$2v-1 = 2vq;$
$(2v-1) / 2v = q;$
$1 - (1/2v) = q;$

Not surprising, the less one values attention, the more willing s/he is going to be to adding citations. The more one values attention, the less willing s/he is going to allocate towards citations.

4.2 Decomposing an existing system into a system that uses attention as medium of exchange

4.2.1 Mechanism design to limit phishing in banking applications



In some online banking systems, when a user creates an account, a personal security image is created. The rationale is that the image is unique and stored in the bank's system only accessible by the associated user. Phishers will try to recreate the banking interface in attempt to deceive an unsuspecting user into giving the phisher valuable and confidential information. The phisher cannot completely recreate the interface because s/he does not have access to the personalized security image.While this system seems to have little to do with attention, there is a secondary activity that occurs in which attention as medium of exchange supports the design of the system. In other words, if a user doesn't pay attention to the fact that the security image changed, the system designed to limit a phishing attack will fail.

In this model we have three market participants, the market of consumers, the intermediary (the banking system), and the phisher. The components of interest that the banking system

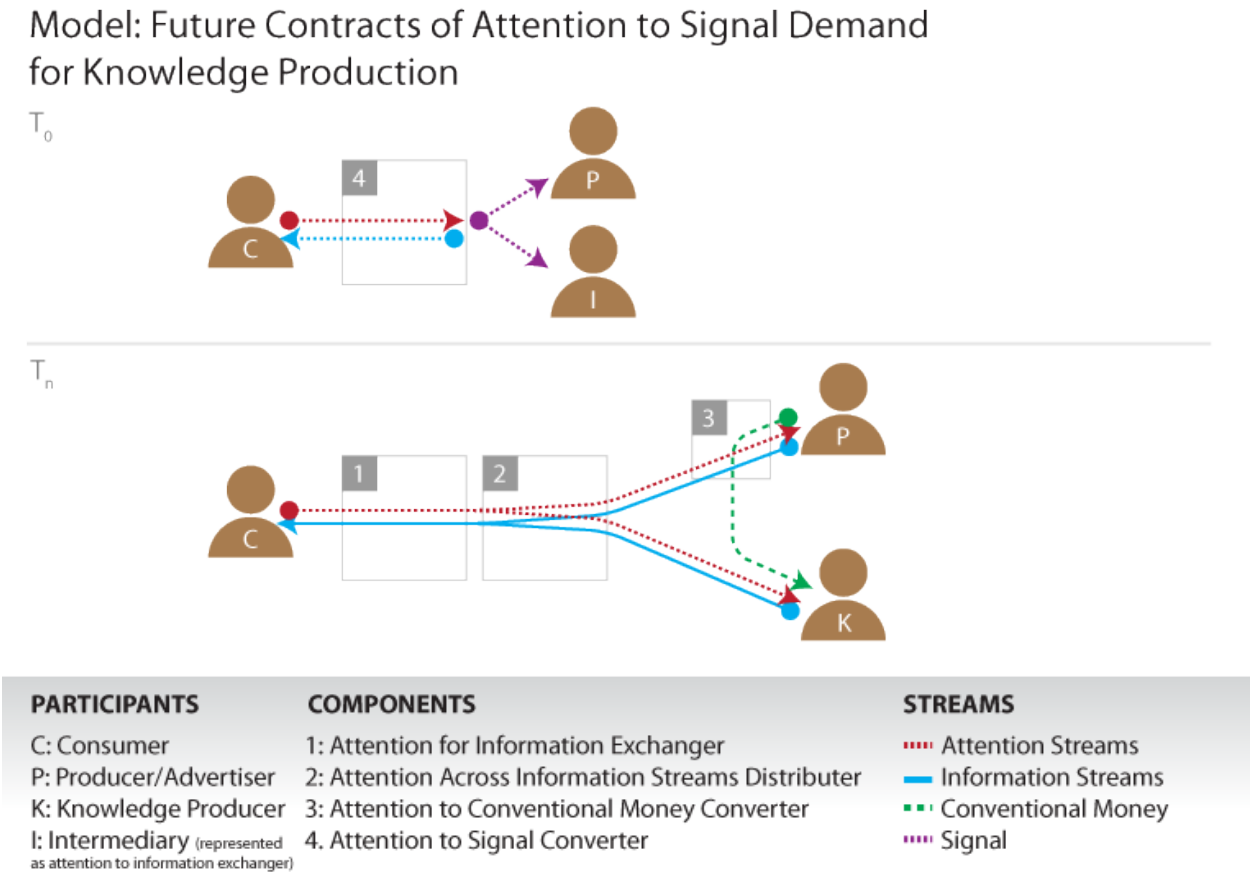
incorporates are the "Attention Limiter" and "Attention Across Streams Distributor" component. We can consider that the information stream is instantiated when a user accesses his or her own account. The attention that can be gained from any interface element of the banking system is limited, and consumers adapt by paying little attention to the interface. The value to the consumer, much like the scientific economy, is derived from the certainty that the limiter creates.

Unlike advertising, the phisher gains a negative utility from attention paid to him or her. Because the phisher does not have access to the limiter (i.e. the personal security image), when the phisher attempts to hi-jack the system, s/he inadvertently advertises him or herself by producing information that induces the consumer to pay a lot of attention at the point that is most crucial. If the low value of the new information drives the expected value of the future information stream below the consumer's opportunity cost, the consumer will abandon the stream, and the phisher fails at his/her attempt. In addition, it should be noted that for this system work effectively, the phisher did not necessarily have to inform the consumer of his/her true type. In other words, the phisher only had to produce low enough valued information.

Also, as mentioned before-hand, unique characteristics of attention can in some cases allow for unrealizable design using typical mediums of exchange. In this case, the non-transferability and non-durability of attention enables the system to work more effectively. This is to say, the phisher is induced to reveal phishing-limiting information, but s/he does not gain anything from the exchange. If attention could be transfered, then the phisher may still have an incentive to phish even if s/he only gained attention.

4.3 New systems using attention as a medium of exchange

4.3.1 Future contracts of attention to signal demand for knowledge production



The advertising model was premised on the notion that consumers engage in an information stream that already exists. In other words, each exchange is a take-it or leave-it offer with no opportunity for consumers to express demand for information or knowledge. For instance, when an individual navigates to Wikipedia.org or Google search results, s/he is given information and advertising that has already been created in the past. A simple adaptation to that model can allow individuals to signal the demand for the production of knowledge in the future.

In this model we have four market participants, the consumer, an intermediary, producers of knowledge, and producers of advertising. The intermediary has no functional role other than acting as "Attention for Information Exchanger" component. The other components used are "Attention Across Information Stream Distributer", "Attention to Conventional Money Converter" and additionally the "Attention to Signal Converter". In order for the system of exchange to start, the consumer converts attention into a signal indicating that future attention would be paid for knowledge if it were produced. A signal is produced because the consumer is

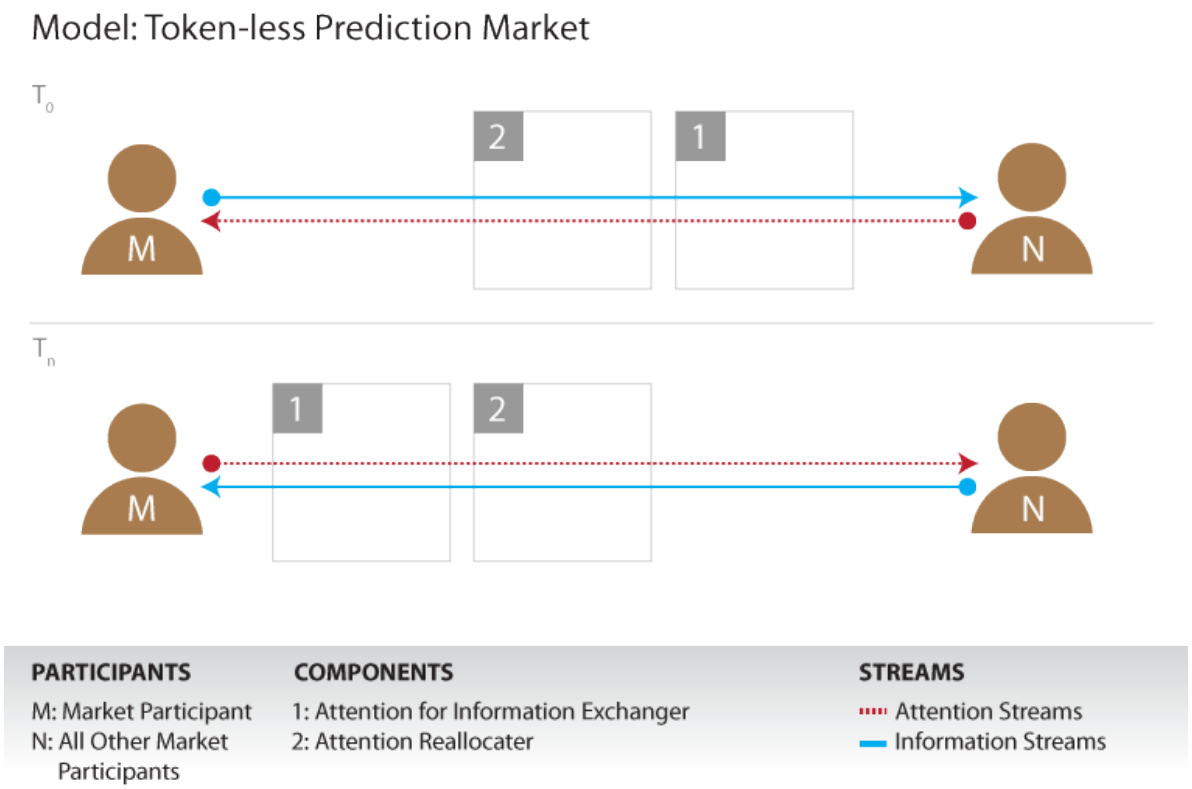
consumes information that is of lower value than his/her expected opportunity costs. For instance, an individual may produce a signal by solving a Captcha to express "I want information on the economics of attention".

Contracts on attention could be difficult to enforce and verify. If an individual pledges to pay X units of attention, later on that individual can simply pretend to pay attention while attending to something else. In addition, there is a lack of any instrument to reliably measure units of attention (if units of attention are even the most appropriate way to talk about attention). The contract will have to be self-enforced by the way in which the system is designed. For this model, we assume that the signal is a good indicator of future attention, but that the quantity and quality of attention is not verifiable.

Upon a consumer signaling intent to pay future attention, knowledge producers can decide whether to produce knowledge. Given no incentives, the knowledge producers will certainly shirk. On the other hand, the advertisers in the system will compensate knowledge producers for effort, and the advertisers wish to participate in the system because they gain value from attention paid.

We structure the model such that any future state of the information stream is the same value to the consumer. In other words, the consumer is indifferent between any contract in time. Again, we assume that the consumer has signaled that s/he is at least willing to pay attention in the future. We also assume that as knowledge producers input knowledge into the stream (or article, such as on Wikipedia), the value of that stream to the consumer increases. Similarly to the advertising model, we can spend down the value the information stream by dynamically including advertising. If the information stream has little information, then no advertising will appear. If there is a lot of information, then there will be a lot of advertising. One possibility is to include advertising based on unique keywords entered by knowledge producers. As long as the future information stream is of higher value than the consumer's future opportunity costs + time preferences + advertising, then the consumer will desire to pay attention in the future. It is entirely up to the consumer when to pay attention (e.g. a day, a week, a year). In other words, the system is designed such that the any future state of the information stream is worth the consumer incurring the initial cost of producing a signal. By not determining any aspects of exactly when the consumer will pay attention, the contract is always enforced by the consumer, not the knowledge producers or advertisers. As stated before-hand, enforcement by the knowledge producers or advertisers would be difficult.

4.3.2 A token-less prediction market



Prediction markets are effective mechanism to aggregate information and reducing uncertainty of future events. Governmental regulation or social stigma can inhibit the use of money which would provide incentives to participants to invest attention and submit information. In addition, the list of items that exist in prediction market may suffer from mis-allocation.

In this model we have two market participants, a market participant valuing a reduction of uncertainty of future event, and all other market participants who may or may not have information that can reduce uncertainty. We assume because attention is finite, all market participants have some information of future events they are certain about and are uncertain about other future events in which a reduction in uncertainty is valued. In other words, the market is such that participants would value exchange if it could be sustained. This model only needs the "Attention Reallocater" component.

Market participants desiring a reduction in uncertainty face one hurdle, they need others, especially those whom have information, to pay attention. Paying attention has an opportunity

cost, and certainly those with information have no incentive to contribute. On the other hand, if we can structure it such that in the future when contributors need to seek attention they have some influence to command attention, we can induce contributors to pay attention and submit information.

Let's assume that individuals can submit questions where answers fall in the range of 0-100. A future event will occur such that the answer is indisputably one of the values from 0-100. Predictions where the future event has yet to occur will be referred to as an unclosed prediction. When an individual stumbles upon an unclosed prediction, she or he can specify a range of values that s/he feels 100% confident in. If s/he specifies the range 0-100, then s/he has reduced no uncertainty in the unclosed prediction. If s/he enters a range that is tighter than what is presented, then s/he has reduced uncertainty given that the prediction is correct. Alternatively, as explained below, s/he may want to specify a range wider than what is presented, indicating that s/he is adding uncertainty to the unclosed prediction.

The Attention Reallocater component take all unclosed predictions and sorts them based on highest to lowest uncertainty every time any individual inputs information. Unclosed predictions with the highest uncertainty are placed at the top of the queue which increases the amount of attention paid by market participants. In other words, the reallocater is a list, and people pay attention to the top of the list first, and so on. When an individual first enters the system (or under other circumstances as detailed further on), the system treats that individual as instrument of prediction ability no better than a random gamble. In other words, a 100-sided die will give us the same prediction. The system attributes a 0 to this individual. Individuals can pay attention to unclosed predictions and submit predictions that will improve how the system views him or herself. If an individual won a prediction by specifying the exact number (i.e. the tightest range possible), then the system would view the individual as an instrument of perfect prediction ability and attribute the highest possible number to him/her—a 1. By making correct predictions with tighter ranges, one increases his/her prediction ability towards 1.

One can spend down his or her prediction ability by simply stating uncertainty in his/her own or other unclosed predictions. For instance, if I have a 1 prediction ability, and I state in an unclosed prediction my confidence is 0-100 (i.e. a random die), I spend down my prediction ability all the way to 0. Because the reallocater sorts based on uncertainty, by spending all of my prediction ability, I push that item highest in the queue, thus, allocating more market attention to that item. Of course, an individual can state any range s/he feels confident in. The more an individual increases certainty, the more s/he can command future attention by submitting uncertainty. As well, when an individual pays attention to an unclosed prediction, the range displayed is the aggregate prediction range submitted by previous market participants. Lastly, an individual can only increase uncertainty if his/her prediction ability is greater than 0, otherwise s/he can only submit ranges that are tighter than presented. Also, an individual can only submit an uncertainty range such that the range will not spend the prediction ability below zero.

In this system, individuals are incentivized to reduce uncertainty because doing so allows greater command of attention in the future when reductions in uncertainty are valued.

5 Conclusion

We've presented a framework premised on attention as a medium of exchange. From this premise, we built a framework that accomplishes several goals—unifying disparate literature on the economics of attention, a way to visualize existing or new systems using attention, and enabling such systems to be analyzed from an economic perspective. By designing and analyzing a variety of models, we demonstrated the validity and broad applicability of this framework. While we make no claims on definitively solving inefficient allocation of information, this framework and insights can guide future system design and economic analysis such that we are making improvements.

6 Future Work

While only brief introduction, this broad applicability of this framework is amenable to a wealth of topics that can explored in the future. The framework rests on a host of assumptions such that further exploration can only increase our understanding.

- How do individuals determine expectations of value of information streams?
- How do individuals determine expectations of opportunity costs?
- What system designs will increase accuracy of expectations of value and opportunity costs?
- How do individuals determine when to be attention-seeking?
- How can equity of attention be used in system design?
- How do we incorporate more elaborate descriptions of attention? For instance, attention is discussed as gradient in psychological literature where individuals pay attention at differing levels to information (Kahneman 1973).
- When is it inefficient to use attention as medium of exchange, and why?
- We assumed that individuals had no incentive to hide information. How do system designs change when we include such motivations?

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