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The Market for Self-Sovereign Data

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Abstract

This paper describes the design of a decentralized, real-time, digital market for private information in a property system where individuals can hold entitlements to the information ie. self sovereign data. It describes the current system where individuals cannot hold entitlements and the challenges it presents, as it would require the focus on the information itself and the rights over it. In a property system where individuals can hold entitlements, the challenge is the bargaining solution and scalable market structures. The paper presents a market design and implementation for the new property system and a pricing model for the information within the market.

Introduction

There has been much written about whether information can have property rights per se. Liddell, Simon and Lucassan (2021) provided an excellent treatment on this topic. Their conclusion is, as also noted by several other authors in the past, that information cannot be a subject of property, but other forms such as inventions or databases would qualify under an intellectual property framework with rules such as eligibility, criteria, scope and duration of protection etc. in place such that a successful system of property could prevail. Liddell et. al. further goes on to state, however, that individuals would rarely be considered owners of the information within such a qualifying framework as they are not the generators of the information nor did they collect it in the first place.

While it is true that individuals would not normally be owners of such information, what would a successful system of property be if they could?

The technological capability of organisations in collecting, generating, using and sharing real-time information on demand in digital markets is that of owning technical devices such as cloud servers and databases, and the ability to control, store and process data. That they have intellectual property rights over the information and therefore hold entitlements, is not disputed. If individuals have the same capability, and therefore also be able to hold entitlements, how would markets emerge from such a system of property and what are the economic rents that could result?

Of course, having the ability to hold entitlements is not the same as actually having the information, since much of the information is generated by firms and therefore resides elsewhere.

Nonetheless, it is an important starting position as the ability of individuals to hold entitlements brings about their ability to contract on any potential future entitlements and that makes Coasian Economics relevant. Coase proposed that, under the right conditions, any dispute over property rights could result in an optimal solution economically, regardless of how the property rights are distributed in the first place, as long as parties have the ability to bargain and transaction costs can be kept low (Coase, 1937). Farrell calls this a "decentralization result" (1987), where "if such-and-such conditions hold, then selfishly optimal individual decisions will lead to efficient aggregate outcomes". Thus, if a system of property can exist where everyone (individuals and firms) can hold entitlements in an equal manner, efficient bargaining can occur.

Axiom: the Entitlements of Natural Persons

For the purpose of legal clarity, we will refer to parties with the ability to contract as legal persons (which could be non-human such as an organisation or a sovereign state, or human if they are able to contract) to differentiate from natural persons who are human. This distinction matters as the subject matter of this paper - that of real-time digital private information - may impose inalienable restrictions on transferability, ownership, and its use by legal persons may differ contractually if legal persons are natural persons contracting for themselves.

This paper begins with the axiomatic principle - *that natural persons can be legal persons attributed with intellectual property rights over real-time private information in digital markets under current qualifying frameworks of property such as a server and its associated storage system*. This means that both organisations and individuals can therefore hold entitlements in the same way. On the basis of such an axiom, all natural persons on the Internet are legal persons and can enter into contracts for their entitlements.

An important clarification of the axiom is that we are not proposing that information be propertized; extant literature has discussed extensively on the negative consequences of such a concept including, for example, incentivising privacy for sale etc. Liddell et al's treatment of the issue is comprehensive in why that is a bad idea. Instead, our axiom is on rights over information held at rest with the same processing, computation and storage capability of organisations; the ability to use and to transfer, the right to exclude, the right to give rights; in other words, entitlement **not** of propertized information, but to the qualifying framework within which the information resides in.

By entitlement, we mean legal entitlements that are expressed in most work on property rights, including intellectual property rights in law and economics and we adopt Rose-Ackerman (1985) classification of entitlement rules by ownership, use, and transferability.

The Property Systems in Digital Markets

Under any property system, entitlement holders of information face different restrictions on the ownership, use and transferability of their property. These restrictions can be due to regulatory concerns, designed to produce some benefit or prevent some undesirable activity. We replicate the Rose-Ackerman taxonomy below for the purpose of classifying the system and apply them on 2 property systems - the first without entitlements and second with entitlements.

Table 1: Use-Restrictions in use

	Restrictions on **Use** of Information by all legal persons		
	Nothing is required	All permitted activities are also required	Some permitted activities are also required

Nothing is permitted	1		
Nothing is forbidden	2		3
Some activities are permitted and others are forbidden	4	5	6

Table 2: Transferability-disposal of entitlements

	Restrictions on **Transferability** of Information by all legal persons	
	Gifts permitted,	Gifts Forbidden
Sales permitted	Pure Property (A)	Modified Property (B)
Sales forbidden	Modified inalienability (C)	Pure inalienability (D)

Table 3: Ownership-Who may hold the entitlement

Who may hold the entitlement	
Anyone	a
Only some specified groups	b
Everyone simultaneously	c
No one	d

For the use of real time information in digital markets, we would classify both property systems as (2) in Table 1 which means all use of the information by the entitlement holder is permitted with nothing required and nothing forbidden.

For transferability of information, both property systems are classified as (A) in Table 2 where all gifts and sales are permitted. This is the area of intense debate, and why inalienable rules are often put in place to protect individuals and their rights to privacy.

It is in the final table where the classification diverges. Individuals may hold entitlements on private information, such as having them stored on a laptop or device. However, the nature of digital real time information markets are such that individuals cannot contract easily from such entitlements and therefore for such markets, private information of individuals can only

be held by firms as their proxies. This means that for ownership (table 3), existing system is (b). However, if we apply the axiom, we can establish a new property system that is (a).

The two property systems can be summarised as follows:

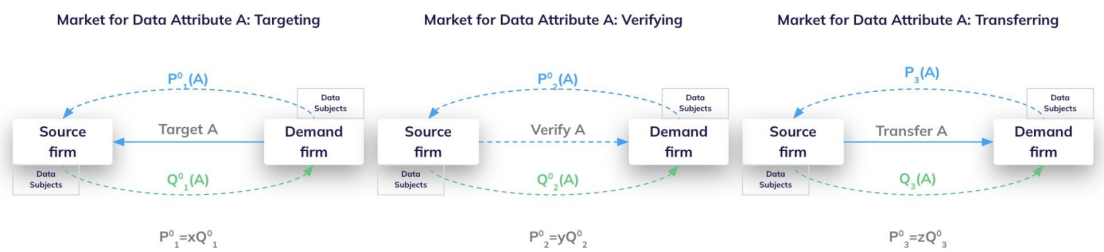
1. Current system in the use of real time information in digital markets where only specified groups (only organizations) hold entitlements, with no restrictions of use and transfer of property **[2.A.b]**.
2. A new system where anyone can hold entitlements, with no restrictions on use and transfer of property **[2.A.a]**.

What are the market rules for this new system of property? There is little guidance on how such a market would behave nor the rules of engagement. While such a system accepts, ex-ante, that all property rights over information belong to any legal person that collects it, it only means that the market will **begin** with all information being held by firms. Bargaining solutions may prevail, but without the existence of a technology that accord such entitlements, efficient bargaining cannot be achieved. Yet, even where such a technology exists, the market structure is not trivial due to the nature of the private information and its inalienable rights. This paper investigates the design and deployment of such a market, the structure under which it could operate and the price of the information in such markets.

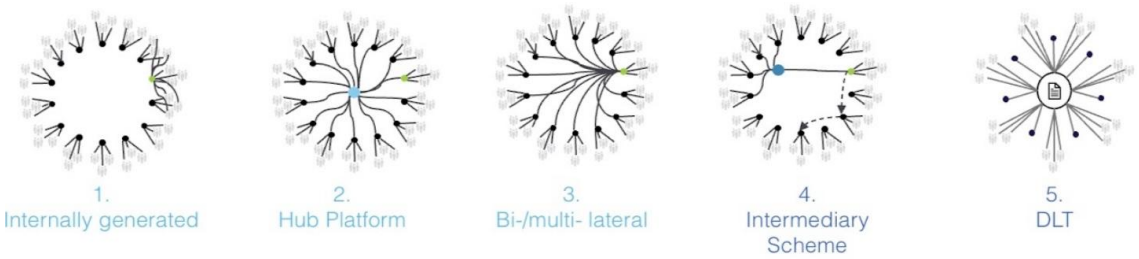
The markets for information

In the existing [2.A.b] property system, since only firms hold entitlements to that information, the trade of private information is between firms.

Three markets currently exist for such information. First, the market for **person targeting** information in advertising where firms pay for target data attributes of persons that they consider attractive for their products e.g. being a mum (attractive for children's apparel), or having a high salary (attractive for luxury goods). Such information is often private information inferred by websites through "cookies" or through social media and constitute a market for that information. Second, the market for **person verification** information where verified information is useful as a qualifier E.g. verifying a person is above 21 to buy alcohol, or verifying a credit score to obtain a loan. Third, the market for the **acquisition/transfer** of the information itself E.g. where the private information is required to consume a product E.g. signing up as a new patient in a hospital would require information to be transferred to, or be acquired by the hospital. These 3 markets characterise the demand not merely for the information but the information about the information (ie the meta information). Certain information can exist in all 3 markets, for example **age**. Age is a targeting attribute in advertising markets, a verification attribute in the purchase of alcohol or other age qualifying services and a transfer attribute in services such as education and health.



Yet these 3 markets do not overlap since the supply of information sits within different firms even if the person is the same individual. Due to its value, the information is sometimes acquired and sold on to data brokers For certain types of information, each market could have its own agents or intermediaries E.g. credit score agencies. Finally, all 3 markets could be coordinated on one centralised digital platform as it is done with large tech companies such as Facebook and Google, earning supernormal profits. Depending on its use (targeting, verifying or transfer), the market for the information could follow several structures such as those below.



With the new [2.A.a] property system, however, because individuals can hold entitlements and therefore can hold their own private information, the market could be designed to be located at the individual level (decentralized) where the individual shares the coordination and matching work through their own preferences. This could make it more viable for source firms to create a market for their data, and in so doing, earn rents, while providing a bargaining solution for individuals to acquire their own information.

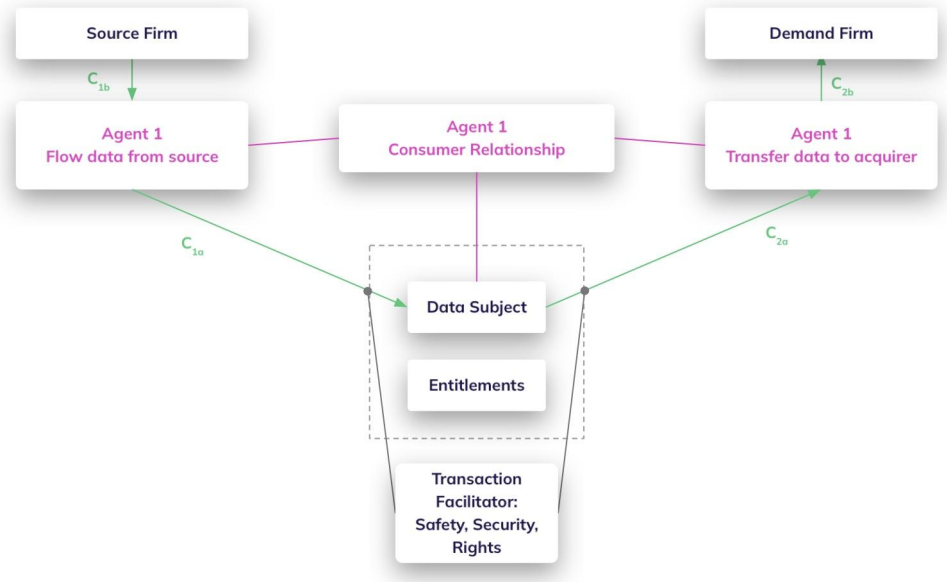
The Market Design

This paper reports on the design of a market for private information for a [2.A.a] property system. The private information here is a single piece, or a set of data attributes that personify the characteristics of a person, held within source firms. We provide an account of the efforts to engineer a micro-economic, decentralized digital market with the necessary thickness, reduced congestion and safety (Roth, 2018).

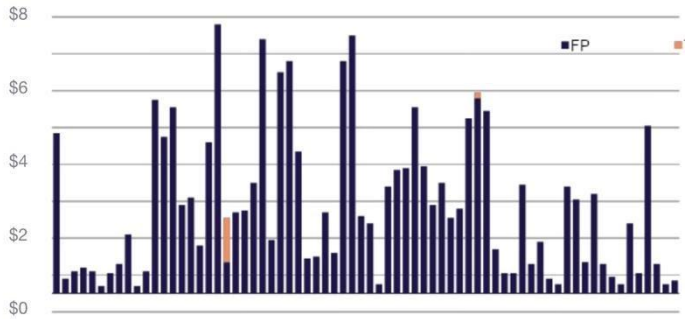
The [2.A.a] property system, which we term as “self sovereign data system” was operationalised through the creation of a Decentralized Data Server (DDS), deployed into a cloud environment and enabling the legal ownership of private information held in a “data account” of the individual. We built the system to be rolled out through an agent acting (under oversight rules) as a transaction facilitator that ensures the safety of data flows, upholds the storage rights of legal persons and executes instructions based on contractual agreements entered into by all parties in the property system. The transaction facilitator has no access to any of the private information flowing within the digital system.

Validation of self sovereign data transaction

The first deployment was a pilot in Brazil using the private information of Facebook data transformed into a risk score for micro lending. The process entailed offering individuals who have failed to obtain a micro loan on a lender’s website due to the inability to signal their risks (because they do not have a bank account) to be given a second chance by acquiring data from Facebook into the individual’s data account, obtain a privacy preserving assessment of the individual’s risk profile from the data acquired, confirm that the risk profile is acceptable and then transfer it to the demand firm in return for the micro loan. This is diagrammatically shown below.



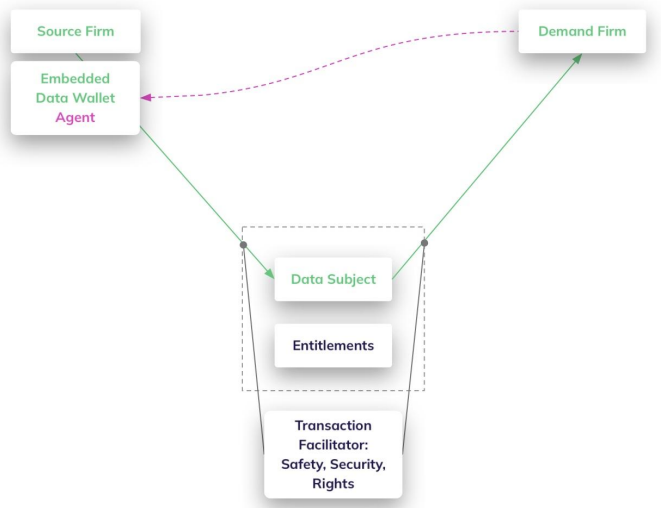
The roll out for this structure led to 2,611 Data Accounts issued from September 2020 to June 2021 with the micro lender, with a reported increase in lending. The price transacted for the information was $0.05 per transaction. A snapshot of the daily revenues by the transaction facilitator is shown below.



The results show that there can be a role for an agent to coordinate a data exchange for private information through a self sovereign data system when a credible source of such data attributes exist and in such a way that is safe, secure and does not compromise privacy. In other words, a bargaining solution can exist but what is the general structure of the market and what is the characteristic of the private information (data attributes) that would be viable for an exchange?

Establishing an agent market for the self sovereign data system

The second design experiment recruited another commercial agent to answer the above questions. The second market structure was similar to the 3-sided market structure in Brazil. However, within 2 months of set up, the 3-sided market was restructured into a 2-sided market when the source firm integrated the agent role.



Our study found that the market structure changed from 3-sided to 2-sided when the source firm was driven by a "triple coincidence of wants". This triple coincidence occurred when the data attribute created the coincidence of:

1. **Demand Firm Targeting, Verification and Transfer**. Demand firms wanting audiences that characterize the particular data attribute with greater accuracy and relevance when compared to targeting from conventional (advertising) markets; and/or able to verify the audience and the data; and/or be able to acquire the data.
2. **Source Firm lock-in**. Source firms wanting to increase **customer switching costs** through the augmentation of its service from complementary offers from demand firms and therefore willing to supply the data attribute.
3. **Individuals' lower search and information cost**s. The audience (individuals) that characterizes the data attribute wants related products and services relevant to the data attribute.

In our designed experiment, a source firm provided weight loss data attributes in a "data wallet" within its weight tracking app to attract demand firms in health and fitness to pay for targeting; with offers and prizes that attracted individuals, creating engagement and lock in for the source firm. Our results showed that data attributes with triple coincidence of wants would result in economic rents for the source firm, a bargaining solution to acquire data for individuals, a willingness to pay the price for targeting and verification around the private information (weight loss behavior) and emerge a viable market.

Modelling the supply price of self sovereign data attribute

We then turn towards creating a general pricing model for the price of self sovereign data attributes that could be supplied by source firms.

Typical price models derive from an analysis of costs and profit. Unfortunately they neglect market dynamics and therefore do not deal with the real value that clients place on the product. Such models put optimal margin at risk. The second type of price model would use sales and forecast to work out the elasticity of the prices and total the perceived real monetary value from the clients with adequate market research. However, gathering such data is complicated and to evaluate the market estimated value for the data attribute requires the use of market research models, eg. Van Westendorp price sensitivity analysis. It

would be also necessary to have sales data, so it can be analysed for elasticity. This is not only cost prohibitive, but also impossible for new markets.

The EVADAS (Economic Value of Data in Use) Model

A third model that we call EVADAS can be a compromise between the first and the second by using data from similar products. This is possible when "similar products" owners already carry out long-term price analysis and when the new product (self sovereign data) offers significant new benefits to consumers and demand firms, constituting an innovative product whose final price cannot be far from the known market price. A price could then be fixed based on the new offered features. In our case, price can be estimated using datasets of similar data attributes sold by Google and Facebook, since both firms use their platforms to sell audiences. We can therefore assess the value of data attributes to a market of firms wanting to reach specific target audiences but extend the estimate of the price when accuracy and relevancy of the same data attributes are enhanced by source firms.

We apply this to 2 of the most common data attributes of private information that has a demand for targeting, verification and transfers - that of **age and gender.**

To be able to estimate the price of the age and gender data attributes, it is necessary to calculate the elasticity of the price for the data attributes so as to infer the optimal price in the decentralized exchange, where accuracy and relevancy is expected to be much higher.

We used the data set for the price model from Google Ads, where data was gathered from different FinTech campaigns.

The development of a price elasticity model consists of the following steps:

1. Data Quality Check
2. Data Analysis
3. Model Assessment

1. Data Quality Check

The data used for the price model comes from Google Ads where data was gathered from different campaigns. The headers for the tables are listed below.

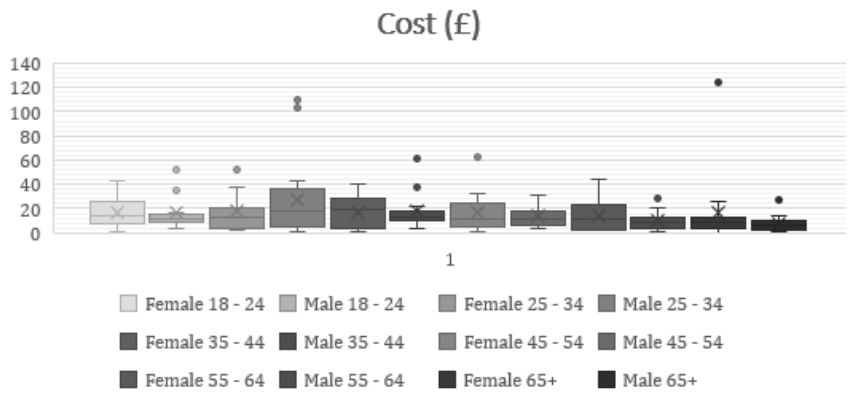
Data Headers Google Ads

Variable	Description
Campaign	Campaign name
Campaign type	Search or Display
Start date	Campaign duration
End date	
Age	Ranks of age
Gender	Female or Male
Cost (£)	Investment per capaign
Impr.	Total impressions of the campaign
Clicks	Total clicks of the campaign

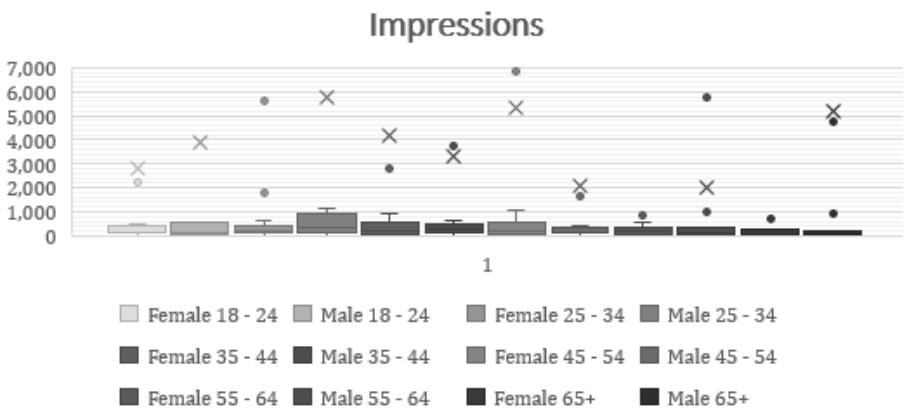
CTR	Click Through Rate
Search keyword	keyword buying by campaign
Search term	term buying by campaign
CPI	Cost per Impression
CPC	Cost per Click
Accuracy	Calculated field
Relevance	Calculated field

2. Data Analysis

A box-plot was performed for each variable, the goal is to get a general perception of the data.



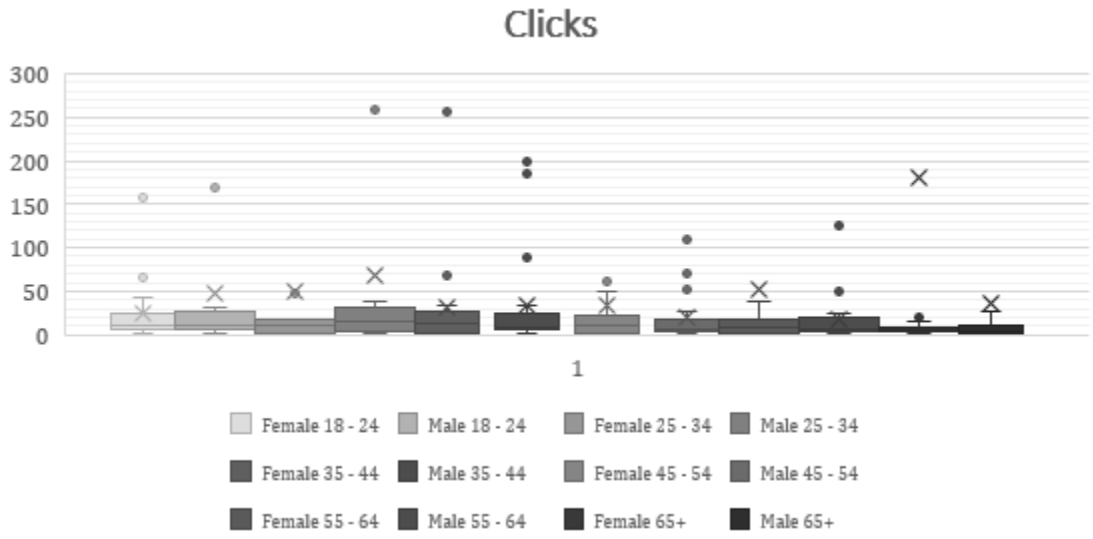
Note that for Impressions, two campaigns were excluded. Just for visual purposes (they were included for the modeling).



Impressions	Display - [Google Build] - UK	More Data #2
Female 18 - 24	36,456	8,895

Male 18 - 24	29,845	25,236
Female 25 - 34	163,127	5,637
Male 25 - 34	55,241	34,416
Female 35 - 44	60,217	2,817
Male 35 - 44	34,555	17,513
Female 45 - 54	85,778	6,873
Male 45 - 54	25,700	7,378
Female 55 - 64	171,499	873
Male 55 - 64	24,507	5,782
Female 65+	444,001	692
Male 65+	81,754	4,785

Likewise, the plot for Clicks ignores a Campaign for visual purposes. All the campaigns are used in the final model.



Clicks	Display - [Google Build] - UK
Female 18 - 24	158
Male 18 - 24	177
Female 25 - 34	693
Male 25 - 34	268
Female 35 - 44	256
Male 35 - 44	185
Female 45 - 54	355
Male 45 - 54	110
Female 55 - 64	666
Male 55 - 64	125
Female 65+	2,806
Male 65+	522

3. Model Assessment

The model used to estimate price elasticity using google data is based on a log-log linear model. The model is defined by the following equation:

$$\log log\ (Cost) \sim a\ +\ b\ *\ \log log\ (Price)\ \ +\ e$$

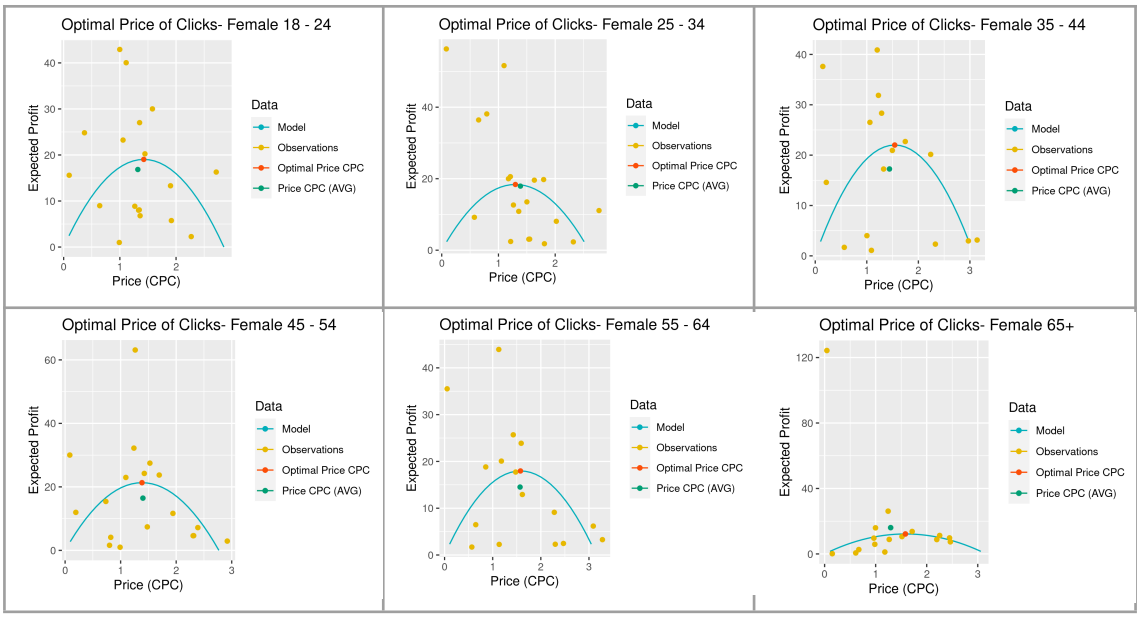
The optimal price was estimated from a quadratic model where the independent variable is price and the dependent variable is Profit (Cost (£)), and only the price that maximizes profit was found.

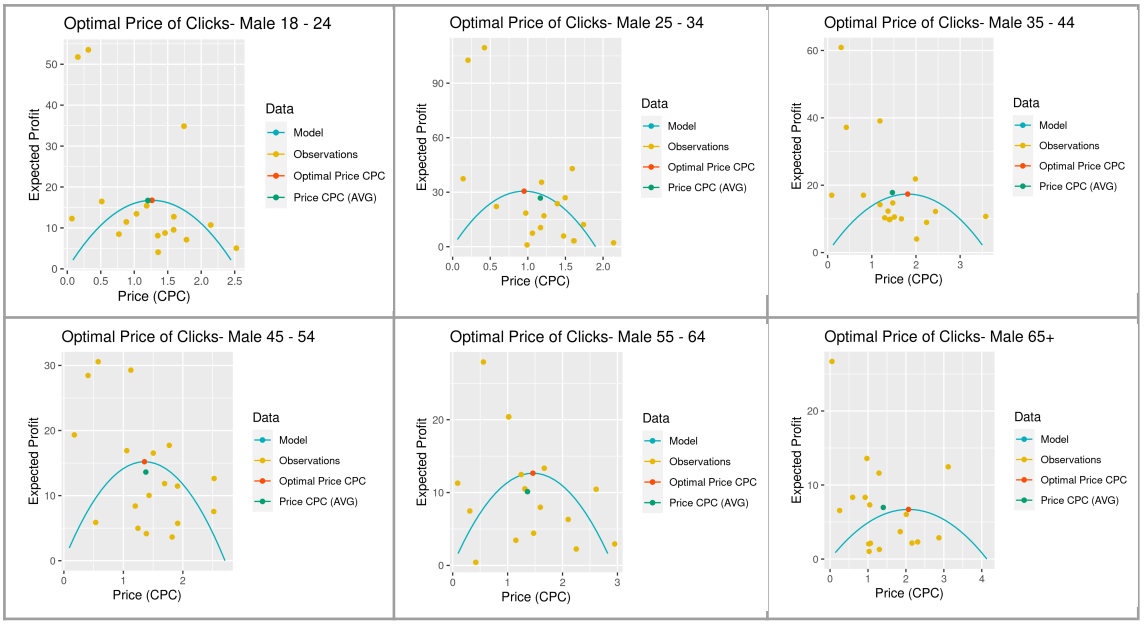
The next plots illustrate the result of the modeling and show how each optimal point can be found.

Optimal Plots

Clicks

The graphics that show the optimal price of clicks (CPC) that maximizes the profit for each target.

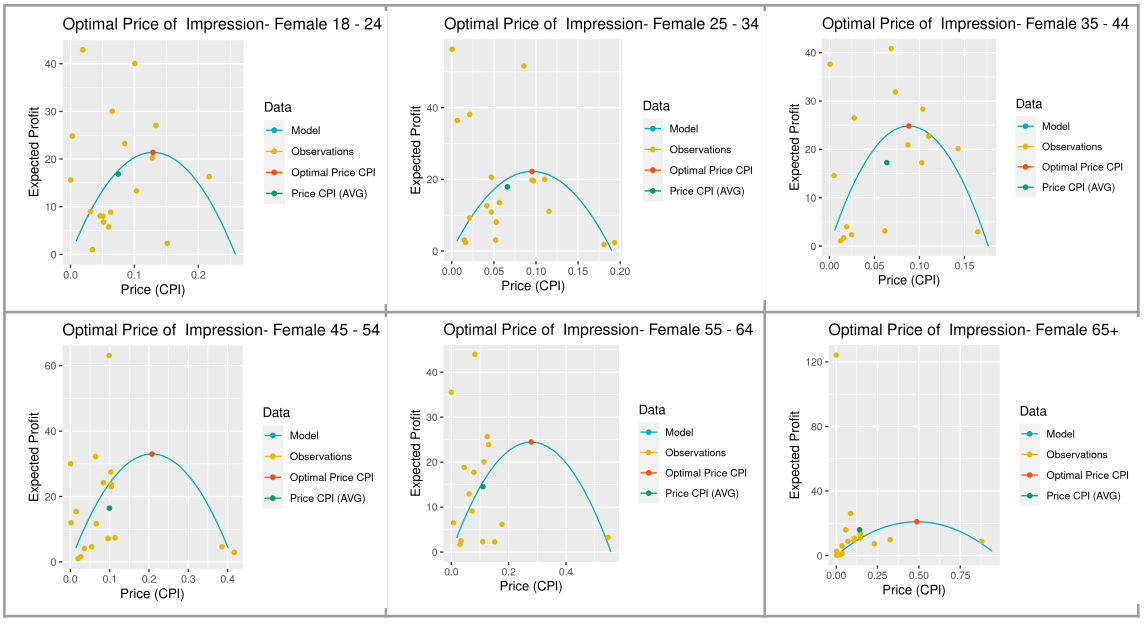


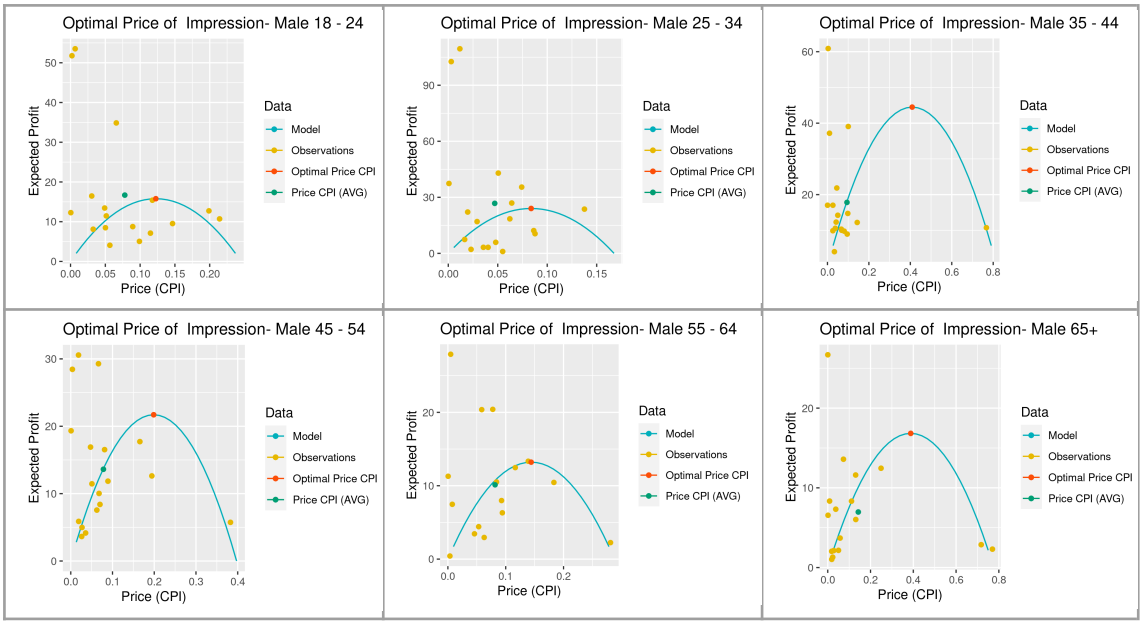


Optimal Plots

Impressions

These graphics show the optimal price of impressions (CPI) that maximizes the profit for each target.





The results of the price-benefit elasticity model for the variables of impressions and clicks for each evaluated target show that most are inelastic demands, that is, the demand of the product is not sensitive to changes in price.

Elasticity Price-Profit Model by Google									
Target	Elasticity Impressions		Elasticity Clicks		Target	Elasticity Impressions		Elasticity Clicks	
Female 18 - 24	0.66	Inelastic	0.12	Inelastic	Male 18 - 24	0.67	Inelastic	0.70	Inelastic
Female 25 - 34	0.67	Inelastic	0.09	Inelastic	Male 25 - 34	0.70	Inelastic	1.12	Elastic
Female 35 - 44	0.58	Inelastic	0.03	Inelastic	Male 35 - 44	0.71	Inelastic	0.00	Inelastic
Female 45 - 54	0.59	Inelastic	0.02	Inelastic	Male 45 - 54	0.65	Inelastic	0.22	Inelastic
Female 55 - 64	0.61	Inelastic	0.00	Inelastic	Male 55 - 64	0.47	Inelastic	0.04	Inelastic
Female 65+	0.43	Inelastic	0.05	Inelastic	Male 65+	0.39	Inelastic	0.38	Inelastic

4. Accuracy and Relevancy

In the development of the Price model, two metrics were identified as crucial:

1. **Relevance Google Ads**. It is the estimated metric that indicates the importance of each campaign generated through the determined search keywords and search terms. For the generation of the relevance metric, each search keyword and search terms were categorized into 7 categorical variables:

Search Keyword & Search Teams	Recoding 1	Recoding 2
cloud computing for businesses benefits	CLOUD	
data policy template	DATA	
data protection	DATA	
ecobank fintech	FINTECH	

finance articles 2020	FINANCIAL	
financial services technology companies	FINANCIAL	SOFTWARE/TECH
financial technology	FINANCIAL	SOFTWARE/TECH
fintech apps	FINTECH	SOFTWARE/TECH
fintech companies in india	FINTECH	
fintech companies to watch	FINTECH	
fintech company	FINTECH	
fintech startups	FINTECH	
heppa laws	HIPAA	LAWS
hipaa	HIPAA	
hipaa act	HIPAA	
hipaa compliance	HIPAA	LAWS
hipaa hotline phone number	HIPAA	
hipaa policies and procedures templates	HIPAA	LAWS
hipaa privacy rule	HIPAA	SEGURITY
hipaa regulations	HIPAA	SEGURITY
hipaa rules	HIPAA	LAWS
hipaa security	HIPAA	SEGURITY
HIPAA software	HIPAA	SOFTWARE/TECH
hipaa violation	HIPAA	SEGURITY
hippa	HIPAA	
k fintech technologies private limited	FINTECH	SOFTWARE/TECH
new financial technology	FINANCIAL	SOFTWARE/TECH
saas cloud computing	CLOUD	
telemart fintech	FINTECH	
top 10 fintech	FINTECH	
wealthtech	SOFTWARE/TECH	
what is hipaa	HIPAA	
what is hipaa law	LAWS	
which of the following methods of information exchange is in compliance with hipaa	HIPAA	
#N/D	N/A	

After recoding the search variables, a PCA (Principal Component Analysis) model was generated, resulting in a total explained variance of 70.6% with three components.

	Component		
	1	2	3
HIPAA	0.879		
LAWS	0.801		
SEGURITY	0.468		
FINANCIAL		0.887	
SOFTWARE/TECH		0.871	
DATACLOUD			-0.789
FINTECH			0.630

The results of the components at the disaggregated level were used to generate a score that will be the result of building the Relevance metric:

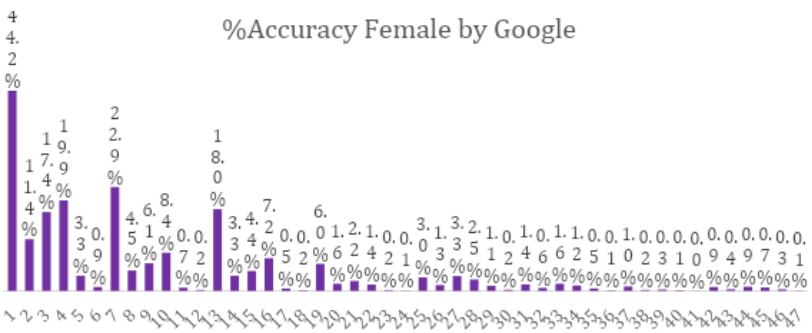
$$Relevance = [Component_{1i} - Min\{Component_1\}] * [Component_{2i} - Min\{Component_2\}] * [Component_{3i} - Min\{Component_3\}]$$

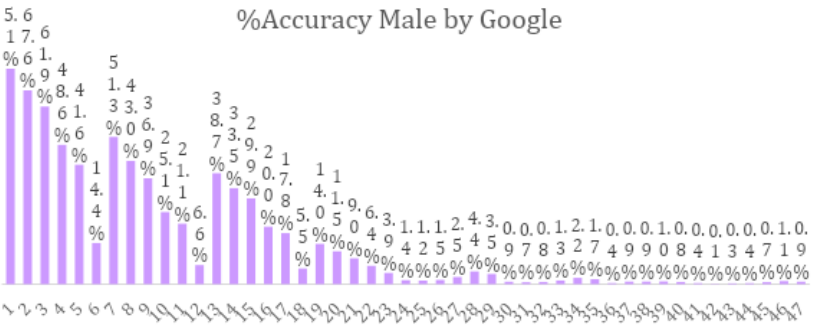
Once the relevance metric is obtained, a linear model is implemented to estimate the optimal price considering the metric, if it is greater than 0%.

2. Accuracy. It is a percentage of impressions that were delivered to an identified audience of a specific profile.

Google Ads.

Based on the recoding applied on the Search variables per Impressions, the %Accuracy results were the following for each of the targets:





Likewise, to assess the impact of the Relevance and Accuracy metrics, a linear model was designed and applied to obtain CPI, CPReach and CPC for both. This evaluation is done as seen below:

$$CPI \sim a + b * Relevance + e$$
$$CPC \sim a + b * Relevance + e$$
$$CPReach \sim a + b * Relevance + e$$
$$CPI \sim a + b * Accuracy + e$$
$$CPC \sim a + b * Accuracy + e$$

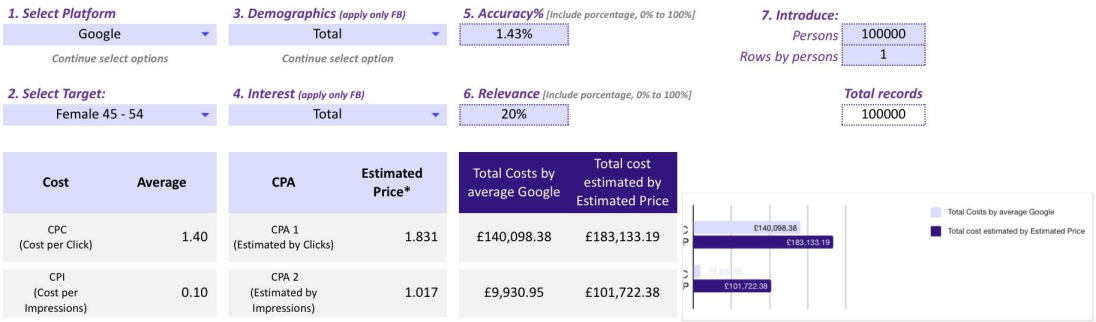
$$CPReach \sim a + b * Accuracy + e$$

Finally, the Total Price estimation is calculated as follows:

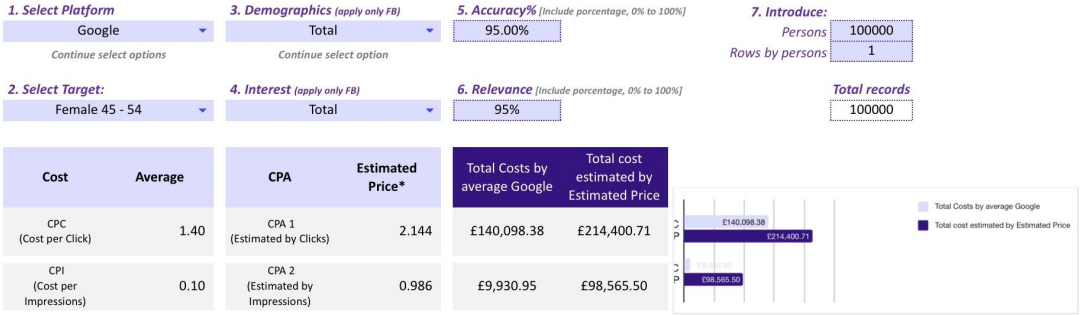
$$Price = Optimal\ Price * b\ Relevance * c\,(1 - Accuracy)$$

Model results and Implication

The first diagram shows the price set by Google for an audience of 100,000 persons for the data attribute "Female, 25-34" at the default accuracy of 1.43% and relevance of 20%.



The second diagram below shows the price of audience targeting of 100,000 persons if accuracy and relevance is 95%



The model provides a way to derive the price of a self sovereign data attribute that has higher accuracy and relevancy, which is when the data attribute could be verifiable by the source firm and where triple coincidence of wants exist. The current model is only priced for targeting. A source firm that can enable all 3 targeting, verification and transfers that self sovereignty allows would be expected to take in much higher rents.

Our study opens up the ability for source firms such as banks, insurance firms and healthcare firms to derive economic rents from the data they hold through such decentralized self sovereign data markets, with price of data attributes varying according to the intensity of the triple coincidence.

Can the market structures of the [2.A.b] property system do the same? Our analyses suggest that they can, albeit with higher transaction costs.

The role of entitlements by individuals serve 2 functions in this market.

First, it lowers coordination and congestion costs as individuals contribute through their own self-selection preferences and the coincidence of their own "want" from lower search costs. This can be also achieved by the [2.A.b] property system but may not be viable due to coordination costs across source firms (interoperability) contributing to congestion in market forming unless intervened by standards and regulatory controls.

Second, since individuals hold their own data, the private information can be transferred and verified with lower transaction costs compared to alternatives of "consent" required from the [2.A.b] property system. At the agent level, coordinating multiple source firms and data attributes, storing, transferring and verifying the attributes, as well as coordinating demand firms without certainty of returns, may also be too costly if the agent is not a source firm. With increasing data regulations and in turn increasing transaction costs on transfers and verifications, Agent markets for transfer and verification in the [2.A.b] property system may also be more costly and less scalable compared to the decentralized, self sovereign system.

Discussion

Even within self sovereign data exchanges, inalienable rights to privacy and restrictions on transferability may need to exist to ensure safety in transaction. Most importantly, the treatment of externalities, namely privacy, would be different. For [2.A.b], inalienable rules such as consent and data protections are imposed for the transferability of information. However for self sovereign data, where private contracts are allowed, different kinds of interventions might be needed, for example reducing coordination costs through private contracts with agents, since entitlements can be held. It is therefore clear that the market rules for [2.A.b] and [2.A.a] property systems would be quite different.

Another key difference between [2.A.b] and [2.A.a] property system is the focus on entitlements v the actual information. [2.A.b] property system has the conundrum of not all parties being able to hold entitlements, and therefore the information itself has to be the focus, and that brings tremendous challenges in the management of externalities as well as coordination and transaction costs, as have been reported extensively in literature. [2.A.a], conversely, does not have such a constraint, and therefore it manages the information assets from within the entitlements, which should lower transaction costs. However, the externalities, coordination problems and distributive goals of [2.A.b] loom just as large for [2.A.a] and they would be salient market design issues.

Conclusion

The market design and implementation reported here investigated the dynamics of a self sovereign data market that could enable optimal and scalable usage of private information. The challenge was not merely market design, but to lower transaction costs.

Overall, our design experiment with a technical platform provided a rule based system where entitlements of data residing with individuals ie. self sovereign data can serve as enabling a market of source firms as agents with individuals partially taking on coordination roles. In so doing, source firms can create scalable multi-sided market for its data for all 3 markets purposes of targeting, verifying and transfer even while information is private. The market design for the [2.A.a] property system is in the process of rolling out into multiple countries. Further studies could report the state of the market and compare its efficacy to the [2.A.b] property system.

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