Monetizing Personal Private Information: A Preliminary Model

Research-in-Progress

Abstract. Information security breaches, Internet search engines, ‘big data’ and intrusive social media have increased awareness of the acquisition, aggregation and use of personal information and sparked discussions about individual privacy. Recent court cases (e.g. right to be forgotten) have suggested that an individual has the right to control their own data, and research has suggested that individuals are willing to give up personal private information (PPI) in exchange for some benefit. This paper develops a preliminary economic model to facilitate the exchange of PPI in a marketplace that consists of sellers (i.e. owners of PPI) and buyers (i.e. entities that want to purchase PPI). The model includes perceived privacy benefits and concerns for the seller, and perceived benefits and risks of acquiring the PPI for the buyer. Model results are discussed along with future research.

Introduction

Recent disclosures and of personal and private information through cyber break-ins (e.g. Target credit card theft) and questionable government-sanctioned actions (e.g. as exposed by WikiLeaks) has sparked a renewed examination of the value of personal, private information (PPI) and ways to protect it. In addition, there is a growing awareness of that information aggregators, firms that collect and aggregate PPI from a variety of public and private sources to sell to other companies or entities, have amassed detailed information on buying habits and finances of private citizens. Consumers are becoming aware of the value of their PPI and the large profits that are generated by third-party brokers. As a result, questions arise about who owns PPI and who has the right to sell, lease or barter it. If an individual owns their own data, a question emerges of how to devise a marketplace to trade PPI between an individual owner and an entity that wants to purchase it. This paper is a preliminary step toward developing a model to facilitate such an exchange.

Under the assumption that an individual owns their PPI, we develop a preliminary model to answer the following questions:

- Based on the literature, what factors influence an individual’s decision to sell PPI?
- Based on the literature, what factors influence a buyer’s decision to purchase PPI?
- What insight into a PPI marketplace can we gain from an exploratory model that implements these factors?

Background

The concept of privacy is certainly not new (Bélanger and Crossler, 2011). Although privacy can be considered a moral or legal right (Clarke, 1999), we use the definition given by Bélanger and Crossler (2011, p. 1018) as “one’s ability to control information about oneself”. Clarke (1998) identified four dimensions of privacy: privacy of the physical person, privacy of personal behaviour, privacy of communications, and privacy of personal data. The last two are often bundled and form the construct of information privacy (Clarke, 1998), and this is the topic we address as PPI.

Studies have shown that privacy is not valued by people as an absolute since they will sell or give it away for economic gain. In this sense privacy can be assigned an economic value (Pavlou, 2011) that can vary over time, situation and person. Smith, Dinev and Xu (2011) refer to a 'privacy calculus' in which "a consequentialist tradeoff of costs and benefits is salient in determining an individual's behavioural reactions" (p. 1001). The cost versus benefit calculus may be different from person to person since each may assign various future discounting values to expected future costs and benefits under different contexts (Pavlou, 2011). Three major components of benefits of information disclosure have been identified by numerous studies: financial rewards, personalization and social adjustment (i.e. belonging to a social group) (Smith, Dinev and Xu, 2011). Research on information privacy concerns has indicated that an individual's perception of risk from disclosure, such as negative consequences and the severity of those consequences, can affect their intention to disclose PPI (Dinev and Hart, 2004).

We develop a preliminary model based on these concepts in which privacy is represented as the seller's inherent utility of not sharing their PPI. Privacy is balanced by benefits of sharing PPI that we conceptualize as the price received from the buyer, and the perceived risk of disclosure of PPI. The buyer balances the utility of the PPI with the cost to provide benefits to the seller and to mitigate the risk of disclosure of the PPI. The model is presented in the next section, and initial results are then discussed.

Model Description

Assuming rational individuals, we use a Hotelling setting (Hotelling, 1929; d'Aspremont et al, 1979) to model an individual's (i.e. the seller of PPI) utility for each firm's (i.e. buyer of PPI) product. In our case, the firm's product is an offer (i.e. monetary incentive) in exchange for PPI from the seller. The buyer can then use the purchased PPI to increase its own profitability.

In particular, we model the seller's behaviour as a Hotelling model in which two buyers are located at 0 and 1 on a horizontal axis. Sellers are located along the line between the two buyers with unit density (total population is normalized to one) and, if utility is increased by supplying their PPI, they will choose to supply to the buyer that results in the largest increase. The market share for each buyer is a function of the PPI's privacy utility of not sharing, price offered for the data, and security risk. In this case, it is best to consider the market share of a buyer as the proportion of sellers who will choose to supply PPI to that buyer.

The seller's decision is whether to supply her PPI and, if so, to which firm? As long as the overall utility of supplying the PPI to one firm exceeds the utility of keeping the PPI private, the seller will supply it. The utility of a PPI purchase offer from firm 1 to an individual at location $x \in [0,1]$ is given by the function $U_1 = \mu + p_1 - \omega(s_1\mu)x$ where μ is the data element's inherent privacy utility to the individual when not shared, p_1 is the price offered by firm 1 for the data, s_1 is the probability that firm 1 will suffer a security breach that exposes that data (discussed below) and ω is the penalty that the seller assigns to that loss of data through a security breach. The utility of a PPI purchase offer from firm 2 is then given by $U_2 = \mu + p_2 - \omega(s_2\mu)(1-x)$. We can solve this system of equations to find the supplier share, d_i, enjoyed by buyer $i, i \in \{1,2\}$.

The security breach probability for each buyer is a function of the sensitivity of the data as well as the investment made by the buyer in protecting that information. We begin with a simplified version of the linear security breach probability function presented in Gordon and Loeb (2002) and set $s_i = \Lambda/(1 + z_i)$. Here, $\Lambda \in (0,1)$ represents the vulnerability of the data while z_i is the investment made by firm *i* in protecting the data.

In this model, we make some important simplifying assumptions. All sellers are assumed to be rational and to tell the truth about their PPI. The inherent privacy utility, μ, for each piece of data can be rank ordered. Thus, the value, μ, need not be known exactly, just that as the PPI data element increases in sensitivity, the value, μ, for that element also increases. Finally, we assume perfect information for all parties – that is, the sellers know both the functional form of the security breach probability function as well as the specific firm investment, z_i. While the value of the acquired PPI data to the buyer is a function of data quality, scarcity, and the collective set of aggregated data; we are considering the PPI as a single piece of data, not a set of aggregated data that may have a higher value when combined.

For the buyer, there are two decision variables – the price to offer sellers for the PPI element, p_i, and the investment in securing that PPI, z_i. The buyers do so by maximizing their profit from the shared PPI. The profit equation for firm i, $i \in \{1,2\}$, is given by $\Pi_i = (v - p_i - z_i)d_i$ for, where v is the value of the PPI element to a buyer. While we propose that $v = f(\zeta, \rho)$ where ζ is the quality and ρ is the scarcity of the PPI element, at this time, we take v as an exogenous dollar amount that the buyer could sell that particular PPI element for on an open market; for example, the price a data aggregator would receive if they sold that PPI element to a third party.

Variable	Definition
Seller's Variables	
$\boldsymbol{U_i}$	Total utility for individual of selling data to firm i
$\boldsymbol{\mu}$	Seller's inherent utility of PPI without sharing
$\boldsymbol{\omega}$	Penalty assessed by seller for a breach of the data.
$\boldsymbol{x}$	Location of seller on the horizontal axis [0,1]
$\boldsymbol{d_i}$	Market supply share for buyer *i*
Buyer's Variables	
$\boldsymbol{s_i}$	Security breach probability function for buyer *i*
$\boldsymbol{\Lambda}$	Sensitivity of the data
$\boldsymbol{\Pi_i}$	Buyer *i* total profit from supply share of PPI
$\boldsymbol{v}$	Value of data element to the buyer
$\boldsymbol{\zeta}$	PPI quality measure
$\boldsymbol{\rho}$	PPI scarcity
$\boldsymbol{z_i}$	Buyer *i*'s investment in security
$\boldsymbol{p_i}$	Price offered for PPI by buyer *i*

Table 1. List of variables

Results

There are two cases for the supply market of PPI: full coverage where all suppliers will always sell to one of the two buyers, and partial coverage where suppliers may choose to sell or not sell to one of the two buyers. Full supply coverage arises when the total utility in the PPI supply market is non-negative (i.e. $U_1 + U_2 \geq 0$). In this full coverage situation, we can solve for the location of the indifferent seller to find that supply share for each firm, $d_i = (1 + z_i)[(1 + z_j)(p_i - p_j) + \omega\Lambda\mu]/(2 + z_i + z_j)\omega\Lambda\mu$ for $i, j \in \{1,2\}, i \neq j$. In the partial supply situation, where some individuals may choose to not share their information with either firm, the supply share for each is given by $d_1 = \frac{(1+z_1)(p_1+\mu)}{\omega\Lambda\mu}$ and $d_2 = 1 - \frac{(1+z_2)(p_2+\mu)}{\omega\Lambda\mu}$. Using first order conditions, we can solve for equilibrium prices and security investment for each firm. These equilibrium values will be non-negative under certain conditions. The conditions depend greatly on the type of market coverage. We shall now present the results for each market coverage situation.

Full Supply Coverage

In the case where all suppliers will always sell to one of the two buyers, the equilibrium values for each firm are:

$$p_1 = 1 - \frac{(1+\sqrt{13})\sqrt{\omega\Lambda\mu}}{2} + \nu, \quad p_2 = 1 - \frac{(3+\sqrt{13})\sqrt{\omega\Lambda\mu}}{2} + \nu$$

$$z_1 = -1 + \sqrt{\omega\Lambda\mu}, \quad z_2 = -1 + \frac{(3+\sqrt{13})\sqrt{\omega\Lambda\mu}}{2}$$

It can easily be shown that when $\omega\Lambda\mu \in [1, \frac{4(1+\nu)^2}{(3+\sqrt{13})^2}]$, then p_i and z_i ($i=1,2$), are non-negative.

To visualize the relationship between the seller's inherent utility of not revealing their PPI and the prices offered, (i.e. to show how the price demanded and security investment required by the seller change as a result of increased inherent utility, μ) see Figure 1a. Here we see that sellers should accept lower prices but demand increased security investments as their inherent utility increases. When the seller holds low inherent utility, μ, then the prices offered are similar for both buyers. However, the security investments by the buyers are very low. As the seller's inherent utility increases, though, security investments increase while prices offered drop. It should be noted that the buyer with the greatest investment in security is also the one that offers the lower price to the seller.

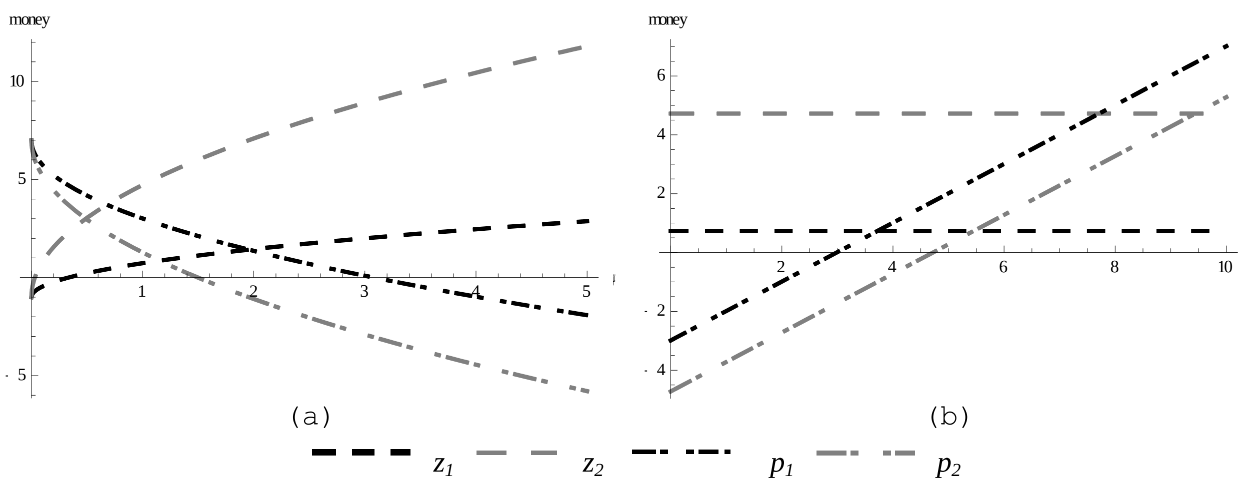

Figure 1. Prices and security investment as function of: (left) increasing seller inherent utility, μ, and (right) increasing buyer value of information, ν.

Similarly, we can examine how the prices offered and security investment change as a result of the buyers' value from the information shared as illustrated in Figure 1b. Not surprisingly, the prices offered increase with the value of the information to the buyers; however, the security investments do not change. That is, the buyer selects his security investment once and holds regardless of the value he places on the PPI. Note, though, that the security investment is dependent upon the seller's utility and risk tolerance, not on the buyers' value assessment. Once again, the firm that makes the highest security investment will offer the lowest price for the PPI.

Partial Supply Coverage

In the case where suppliers may choose to sell or not sell to one of the two buyers, the equilibrium values for each firm are:

$$p_1 = \frac{1 - 2\mu + \nu}{3}, \qquad p_2 = \frac{1 - 5\mu + \nu + \sqrt{\mu^2 + (1+\nu)^2 + 2\mu(1 + 6\omega\Lambda + \nu)}}{6}$$

$$z_1 = \frac{\mu + \nu - 2}{3}, \qquad z_2 = \frac{\mu + \nu - 5 + \sqrt{\mu^2 + (1+\nu)^2 + 2\mu(1 + 6\omega\Lambda + \nu)}}{6}$$

It can easily be shown that when $\mu + \nu \geq 2$, and $\nu + 1 \geq 2\mu$ then p_i and z_i ,($i=1,2$), are non-negative.

To visualize the relationship between the seller's inherent utility of not revealing their PPI and the prices offered, (i.e. to show how the price demanded and security investment required by the seller change as a result of increased inherent utility, μ) see Figure 2a. Here we see that once again buyers should offer lower prices but increase security investments as suppliers' inherent utility increases. When the seller holds low inherent utility, μ, then the prices offered are similar for both buyers. Security investment is low when inherent utility is low, but unlike in the full coverage case, we see that buyers always make some investment. As the seller's inherent utility increases, security investments increase. Prices, however, behave differently for each buyer. One buyer will strictly decrease his offered price while the other will increase price briefly before also reducing price offered. It should be noted that the buyer with the greatest investment in security is now the one that offers the higher price to the seller.

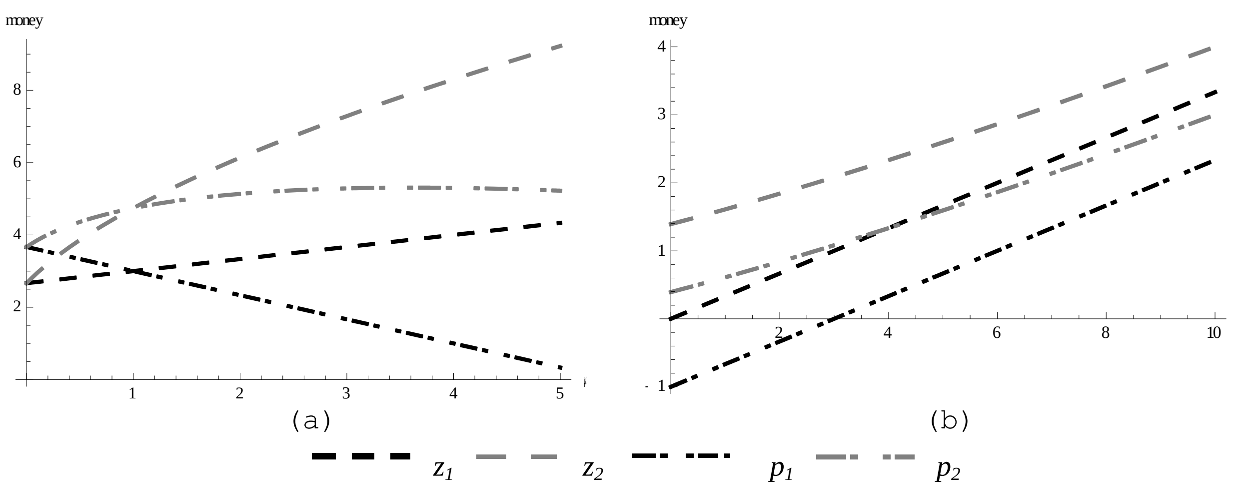

Figure 2. Prices and security investment as function of: (left) increasing seller inherent utility, μ, and (right) increasing buyer value of information, ν.

From the buyers' perspectives, the prices offered are still increasing in ν but now the security investments are also increasing. The firm with the higher security investment also offers the higher price for the PPI.

Discussion and Summary

This paper has attempted to provide a definition for privacy and identify primary factors that influence an individual's decision to sell personal private information (PPI), and factors that influence a buyer's decision to purchase PPI, based on the literature. We found that privacy can be assigned an economic value according to the literature, and that the individual seller has an inherent utility of not sharing their PPI balanced by benefits of sharing PPI that could be expressed as the price received from a buyer and the perceived risk of disclosure of PPI. The buyer also has a utility of the PPI along with the cost to purchase the PPI and the cost of protecting the PPI from disclosure. We developed a model based on a Hotelling setting with two buyers. Under the assumption that an individual owns their PPI, we developed an exploratory model that implements these factors in two PPI marketplaces: the seller chooses to always share her PPI (full supply coverage), or the seller may choose to share or not share her PPI (partial supply coverage).

In the case of full supply coverage, the results suggest that one firm may try to distinguish itself by providing stronger protection for PPI to attract suppliers but that this will come at the expense of the price offered to the suppliers. Such a strategy may entice particularly risk adverse suppliers. In the case of partial supply coverage, the results suggest that one buyer will offer both enhanced security and higher prices in order to attract reluctant suppliers who may otherwise opt out of supplying PPI to any buyers. An observation is that, from the point of view of the buyer, there is a tradeoff between the price paid for the PPI and the cost to protect it, so that as the PPI has higher inherent utility to the seller, the cost to protect the PPI rises, and the price offered must be lowered in order for the seller to optimize profit. This inverse relationship was unexpected.

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