The adoption and diffusion of Privacy-Enhancing Technologies

The factors that drive and impede the adoption and diffusion of Privacy-Enhancing Technologies of private communication and data storage

Master of Science in Management of Technology

Privacy, Security & Innovation

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The factors that drive and impede the adoption and diffusion of Privacy-Enhancing Technologies of private communication and data storage

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Abstract

Privacy and security are perceived as of great importance. However, readily available Privacy-Enhancing Technologies (PETs) and their development, innovation and standardization is not very forthcoming. Indeed, the dominant business model is privacy invasive: gathering and using private data as part of the business model to safeguard continuity. Meanwhile, users want their digital privacy and security safeguarded. The research strategy consists of desk research (analysing transcripts and the literature) followed by a survey to quantitatively analyse and find drivers and barriers of Privacy-Enhancing Technology adoption and diffusion. The research objective is to discover what managerial and policy recommendations can be stated in order to help PET producing organizations to increase the adoption and diffusion of PETs in general.

Keywords:

Privacy-Enhancing Technology, PET, adoption, diffusion, managerial, management, policy, consumer, business, entrepreneurship, privacy innovation

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Preface

I have been able to finish my Master of Science in Management of Technology at a university that transpires, and has been internationally acknowledged to be, one of the best universities in the world. I am grateful to Delft University of Technology as an institute and the people within. In the pursuit of finishing my Master of Science degree I wanted to have a more profound understanding of what motivates me in life. The people working at the faculty Technology, Policy and Management enabled, supported, trusted and allowed me to pursue my goals in the way that works for me. In the process of working towards this thesis I was able to complete over 200% of ECTS (i.e. study effort) of what is officially required of me at twice the speed, including four full specialisations, many additional courses from diverse faculties, the TU Delft Honours Programme and the Leiden Leadership Programme of the Leiden University Honours Academy. To me, my effort is not a mere collection of courses, but a process of exploring and creating a better version of myself. It was an exhilarating adventure that led to this thesis and was a means to show myself what I am capable of. Adventure lies in swimming upstream.

I thank all involved with creating this thesis. My heartfelt gratitude and appreciation goes out to Hadi Asghari. His commitment and engagement, for this thesis and this topic, were an almost tangible thread throughout our collaboration. These qualities are both motivating and inspiring to me. Even though thesis writing is a very structured and analytical process, Hadi made the accurate statement that "thesis writing is messy" and a "creative process" that needs time to coherently synthesize the core of this academic pursuit. There have been times that I struggled with the impasses and breakthroughs that were part of this project. It is easy to be too eager, want to do too much; this means managing oneself.

I am grateful for the patience, understanding and trust I have received by my girlfriend Lilian van Donk. I also thank my parents, Ed and Petra Hup, for their support, my brother, and friends from Delft and The Hague for their patience to pursue my goals. Special thanks within Delft University of Technology goes out to Drs. Ton Valk and Dr. Robert Verburg for admission to the TU Delft Honours Programme and the many inspiring teachers within the faculties of Technology Management and Policy, Industrial Design, Mechanical Engineering, and 'Computer Science, Mathematics and Electrical Engineering'. I also thank the team of the Leiden Leadership Programme. A heartfelt gratitude goes to numerous individuals that gave me valuable insights and have motivated me to pursue challenging goals over the years. Most notably, the insightful foundation that a good challenge is at the core of what motivates me and how to finish my Master of Science degree was laid at the Ds. H.J. Drostschool MAVO. Thank you all very much.

Being among people that bring out the best in each other and remain supportive, will make a world of difference in achieving ones goals.

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Executive summary

The feature of privacy and security in products and services may be both hard to create and hard to monetize as primary feature. Instead, privacy and security typically supports the core business. Meanwhile, Privacy-Enhancing Technology (PET) producers have to compete with ever more privacy invasive products and services that are very profitable. However, PET adoption and diffusion is desperately needed to protect digital privacy as a basic human right (United Nations, 1948) (Council of Europe, 1953).

The problem statement is that PETs have not become a standard and widely used component in system design (Domingo-Ferrer et al., 2014, p. iii). Indeed, there is a lack of adoption and diffusion of PETs. To further complicate the adoption and diffusion of PETs, start-up firms, as well as mature firms often don't have developing Privacy-Enhancing Technologies as a high priority (Hoffman, 2014).

The purpose of this thesis is to establish what factors form drivers and barriers to Privacy-Enhancing Technology (PET) adoption and diffusion. Therefore, the research question is "What factors are drivers and barriers to the adoption and diffusion of Privacy-Enhancing Technologies in private communication and data storage?" The problem owner is in the first place the PET producing organizations. In the second place, the European Union which could facilitate PET producers.

The adoption & diffusion of PETs can be conceptually modelled to five categories. The dependent variable category is: Adoption & diffusion. The four independent variable categories are:

1. Business viability and sustainability
2. Knowledge and innovation environment
3. Design values
4. Research and development.

For consumer demand it seems that *strict privacy core values* is deemed the most important driver for consumer PETs. The *reliance on (not yet available) 3rd party technology & infrastructure* is the strongest barrier found.

For business demand it seems that the strongest driver is the *promotion and support of PET development*. Also quite a strong driver is the *inter-organizational connectedness*. Moderately strong drivers are *strictness of labour laws* and *external guidance*. A strong barrier is the *user's ability to try out interoperability*.

For PET developers the implications of the consumer demand model shows the most profound issue to consider when developing: adhere to strict privacy by design values. Privacy as a strict core value in the PET products/services have the largest effect on consumer demand and thus adoption & diffusion.

Furthermore, inter-organizational collaboration should be seriously considered by organizations if they haven't done already. It is one of the strongest drivers for business PET adoption and diffusion.

In contrast, interoperability between PETs seem to form a barrier for business PET adoption and diffusion. However, the reason for this is not clarified by the questionnaire results. Possible reasons are legal (e.g. contracts, licensing) issues on the one hand, and the difficulty to create a business case that necessitates actors to share information (e.g. sensitive business information) to enable interoperability on the other hand. Hopefully, inter-organizational collaboration will turn the effect of this barrier around.

The promotion of PETs by data protection authorities (Domingo-Ferrer et al., 2014, p. 53), the creating user awareness and promotion of PETs by the research community (D' Acquisto et al., 2015, p. 51) are recommendations that seem to be supported by the findings in this thesis. However, it must be added that facilitation would sometimes be better than delegation: the European Union could play a more active (e.g. facilitation) or even leading role in bringing actors together than is portrayed in ENISA recommendations. Such facilitation could come in the form of a European platform to collaborate and allow PET producers and users to find each other. Especially in the case of weak ties (Granovetter, 1973), that potentially yield novel insights and/or contacts, such a platform would be invaluable. Above all, the European Union could ease the bureaucratic burden for micro and small organizations so they too will profit in greater numbers from public monetary support while minimizing time spent on secondary activities (e.g. paper work). Consequently, more organizations may overcome the difficulties of maintaining or starting a new project which may drive the adoption and diffusion of PETs.

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Abbreviations

Abbreviations used in this document are listed below in expanded form.

AI	Artificial Intelligence
CITP	Center for Information Technology Policy
CPU	Central Processing Unit (i.e. processor)
ENISA	European Union Agency for Network and Information Security
GDPR	General Data Protection Regulation
HDD	Hard disk Drive
ICT	Information- and Communication Technology
IoT	Internet of Things
MIT	Massachusetts Institute of Technology
MoT	Management of Technology
OS	Operating System
OTF	Open Technology Fund
PDF	Portable Document Format
PET	Privacy-Enhancing Technology
PETs	Privacy-Enhancing Technologies
RAM	Random Access Memory
R&D	Research & Development
SSD	Solid State Drive
TU Delft	Delft University of Technology

Glossary

Definitions of terms used in this document are listed below.

Big data	Very large unstructured data sets that may be analysed to reveal associations, patterns and trends relating to human behaviour and interactions.
CPU	The Central Processing Unit is a at the heart of a computer system communicating with all other components and executing instructions such as calculations.
GDPR	European regulation that replaces Directive 95/46/EC.
GPU	A Graphical Processing Unit is responsible is optimized and responsible for graphical data processing.
Optane (a.k.a. X-Point)	A new type of non-volatile storage with the combined benefits of RAM speeds on the one hand, and the low-cost and non-volatile properties of SSD on the other.
PDF	A file format to present documents independent of application software or OS.
PET	Privacy-Enhancing Technology. A technology that respects, enhances, and preserves privacy. It can be both hardware or software, and a product or a service.
Processing power	The processing power of a computer is the amount of data it can process in a certain amount of time. It refers to how fast and powerful a computer system is and if often limited by a certain bottleneck, for example the hard disk, CPU, GPU and/or RAM.
RAM	A volatile type of memory having access times of nanoseconds which is slower than processor (CPU) speeds but much faster than milliseconds access times of a hard disk drive (HDD) and microseconds access times of a solid state disk (SSD).
SSD	A type of non-volatile NAND storage that delivers much higher transfer speeds than a mechanical hard disk drive (HDD).
Write cycle	There are a finite number of NAND flash write cycles, for example in an SSD. The cell becomes inoperable when a cell is written more times than specified by the manufacturer due to normal wear and tear of operating the cell (i.e. writing to the cell).

1 Introduction

The feature of privacy and security in products and services may be harder to create than most other features. Above all, privacy and security in itself is in most cases not a viable business model. Rather, privacy and security supports the core business, not in the last place because of laws and regulations. Uncovering what inhibiters are preventing firms from incorporating privacy & security in their products & services might lead to a better understanding and ultimately fertile ground for progress. This progress should be focused on incorporating privacy & security in the technical design and business models at conception of a product or service, not as an afterthought.

The problem statement is that there is some tension between gathering and using private data on the one hand and privacy on the other hand. However, start-up firms, as well as mature firms often don't have developing Privacy-Enhancing Technologies as a high priority (Hoffman, 2014). Even though privacy and security have been core values of individuals in democratic societies for many decades (United Nations, 1948) (Council of Europe, 1953), only in recent years governments have started intensifying their attention on privacy & security. In 2014 the European Union Agency for Network and Information Security (ENISA) researched the "Privacy by Design" paradigm (Domingo-Ferrer et al., 2014, p. 48). However, the report states that the research community is only loosely interlinked with practice and that better incentives for compliance, including sanctions for non-compliance are needed. In addition, eight key recommendations are given but lack defining responsibilities to specific actors.

The purpose of this thesis is to establish what drivers and barriers affect the adoption & diffusion of Privacy-Enhancing Technology (PET). In the digital age personal data is of increasing value which can be monetized in various ways. Especially very large personal data sets, such as big data, that can reveal patterns and sociological behaviour can lead to a competitive advantage for companies. Invariably, the collection and usage of personal data is inextricably influenced by privacy considerations. The means for companies to gather and extract valuable information from personal data through Artificial Intelligence (AI) and data analytics has increased in recent years. The usage of data in combination with artificial intelligence has led to economic efficiencies for companies concerning monetizing opportunities.

This thesis tries to answer the research question "What are drivers and barriers to the adoption & diffusion of Privacy-Enhancing Technologies in private communication and data storage?"

The contents of this thesis are divided in 9 parts. After this chapter, the second chapter contains the research design. Chapter 3 will elaborate on the literature review. Chapter four contains the used methodology for the quantitative research. Chapter 5 will explain the survey setup after which chapter 6 reports on the data analysis and the created model. Chapter 7 will describe the practical policy and managerial implications of the findings. Chapters 8 and 9 will contain the discussion and conclusion.

2 Research design

This chapter contains the research design. The research design describes what is achieved with the research and how to realise this within the research project (Verschuren & Doorewaard, 2010, p. 16).

2.1 Problem statement

This subchapter contains the practical and scientific problem description to portray the context in which the research project is carried out. The practical problem description explains what problem exists and how this thesis is supposed to contribute to solving the problem. In contrast, the theoretical problem describes the observations that contradict or form a hiatus in accepted theory. Additionally, the theoretical problem forms the basis for the scientific contribution to be made (Verschuren & Doorewaard, 2010, p. 29).

2.1.1   Practical problem

Privacy-Enhancing Technologies have not become a standard and are not widely used in system design. Moreover, the specific implementation of the European General Data Protection Regulation remains unclear at the present moment (Domingo-Ferrer et al., 2014, p. iii).

Nevertheless, the demand for privacy is strong. Among private Internet consumers in 2016, 58% are concerned with their privacy being eroded in messaging software (Buckle, 2016b) and 61% are worried about how companies use their private data (Buckle, 2016a). Privacy concerns do not appear to be a hype as privacy concerns have even slightly increased from 56% of private Internet consumers in 2014 (Mander, 2014). Moreover, the consumer demand for data and communication privacy (Coleman, 2014) (Gigya, 2015) as well as the demand for privacy professionals by companies (Lemos, 2014) is rising.

Whenever privacy invasive activities occur they are not only the result of malicious activities, e.g. from hackers. Indeed, even when consumers hand over their Personal Identifiable Information (PII) willingly, many systems structurally leak intimate private data such as health care data of up to 35% of the US population and up to 29% of the Dutch population in 2015 (Liu, 2017). In half of the US cases the leaks led to identity theft with out of-pocket-cost per person of $2,500 on average (Francis, 2017). In the Netherlands 69.4% of the websites of health organizations do not force a SSL connection which in effect means transferring sensitive personal information in clear text over the Internet (Schellevis, 2017) for anyone to read.

Above all, the call for privacy becomes increasingly more urgent as time passes. In particular, due to advances in science and technology, the ability to collect, analyse and disseminate information has been

radically enhanced in recent decades (Nissenbaum, 2004) (McKinsey Global Institute, 2017, p. 5). Notable advances are made in hardware, software and privacy invasive collaboration. These developments are fuelled by an increasing appetite for data and information.

Recent hardware advances, by Intel and Micron, in storage innovation have resulted in an unprecedented improvement to process information by creating 3D XPoint non-volatile memory (Clarke, 2015). XPoint is commercially released in 2017 under the brand name Optane and has the potential to remove an important bottleneck in processing power: the necessity to separate memory (i.e. RAM) and storage (e.g. HDD and SSD). This means that collection, analysis and manipulation of big data will become real-time in-memory operations, and both be up to a factor 1,000 faster and more durable (i.e. write cycles) than current SSD solutions. Real-time in-memory operations will therefore become economically viable for an increasing number of organizations. However, the software that utilizes the hardware is not necessarily designed with privacy in mind in which case, from a privacy perspective, merely the magnitude at which privacy can be violated increases. Another advancement in hardware that will become mainstream within 5 to 10 years is the Internet of Things (IoT) (Gartner, 2016). This means that information collection, processing and dissemination will become ubiquitous in every conceivable way of daily life due to IoT being all around us, becoming commercial viable and serving as a competitive advantage.

Besides technological developments in hardware, organizations also focus on competitive advantage in software innovations. An important advancement in computer science is machine learning which gives computers the ability to learn without being explicitly programmed. Machine learning is a type of Artificial Intelligence that allows for behavioural profiling and making assumptions about the identify of individuals for monetizing purposes (Witten, Frank, Hall, & Pal, 2016, pp. 5, 26). The awareness of the capabilities of machine learning has peaked in 2016 and mainstream adoption is expected within two to five years (Gartner, 2016). Indeed, the pace of machine-learning breakthroughs is increasing (McKinsey Global Institute, 2017, p. 5). Smarter and higher volume data processing introduces privacy and security risks due to complex data accessibility and sharing among multiple sources. Nonetheless, most organizations lack systematic pre-emptive measures to ensure appropriate data access. And even if most organizations would have such measures, the existing non-big data security solutions cannot be applied to big data because they are not designed to handle the complexity, variety, speed and scale of big data (Kshetri, 2014).

Privacy invasive collaborative developments have the ability to aggravate privacy concerns by utilizing both hardware and software innovation. Data brokers (or: information brokers) collect and maintain personal data of hundreds of millions of consumers. The data is analysed, packaged and sold generally without consumer input or permission (United States Senate: Committee on commerce, science, and transportation, 2013). Besides for commercial purposes also the government has a vast need

for private data and collaborates with the private sector to obtain such data. Building on the Snowden documents, we know governments work with private firms in a vast "public-private surveillance partnership" (Schneier, 2016, p. 6) besides efforts of intelligence agencies on their own (e.g. PRISM) (Greenwald & MacAskill, 2013). The purpose is to gather private data for intelligence purposes. Also less obscure government controlled organizations, such as the U.S. military forces, that have vast amounts of resources (Kugler, 2006, p. 103) have shifted their concerns to knowledge superiority (Kugler, 2006, p. 296) and networked and decentralized operations (Kugler, 2006, p. 300) to remain competitive. These collaborations have the sole purpose of obtaining as much private data as possible without the consideration of privacy.

With all the advances in science and technology society needs more than ever products and services that consider privacy in their design. However, the availability of privacy features in products seem an afterthought, if implemented at all, rather than a fundamental design choice. A great example of encryption being an afterthought is an everyday communication system like Skype that introduced end-to-end encryption years after its launch. In the meantime Skype was able to read chat messages at the back-end (Bott, 2013). Not respecting privacy can also be a deliberate design choice, such as car manufacturers that mine driver data (Paresh, 2016). Likewise, even when users consider themselves to be safe from prying eyes via a VPN connection, app usage data may be shared with organizations such as Facebook (Sulleyman, 2017). In addition, strategic ICT decisions made by Microsoft, such as changing Skype's decentralised architecture to a centralised architecture (Vaas, 2013), indicates that the ability to monitor user conversations is of importance to the company's mission.

From a legislative perspective privacy in undermined also. Some legislative decisions are opaque such as intelligence agencies like the FBI that wants to know all recorded car data in real-time and just taps the car (Fox-Brewster, 2017). However, not all governmental and organizational decisions are opaque. An example is a newly proposed law in Russia enabling telecom providers to hand over personal details of anyone using a VPN service (Andy, 2017). Another example is a newly proposed law in The Netherlands that allows Dutch intelligence agencies to tap a whole neighbourhood when only one household is suspected of wrongdoing (Staten-Generaal, 2017).

The importance of all these developments is that the risk of losing control over how, where and with whom we share our personal lives and thoughts is increasing (Schneier, 2010). This means that privacy itself, which is a basic human right (Council of Europe, 1953), is eroding.

In conclusion, based on the recent radical advances in software, hardware and privacy invasive collaboration, it could be stated that the urgency for Privacy-Enhancing Technologies increases. This urgency calls for researching how society should manage information privacy by design (Domingo-Ferrer et al., 2014) to minimize privacy risks, rather than including privacy as an afterthought in products and services. Nor should we trust in contemporary privacy-respecting legislation because it may

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suddenly turn against its citizens collectively (Staten-Generaal, 2017). Privacy should be the default and by design without an "off switch" so we can trust the systems we use in the future with the same trust that we have in them today. Indeed, the Privacy-Enhancing Technology producers have the power to produce privacy respecting solutions which makes them excellent primary problem owners with the necessary skills and knowledge, as well as amble opportunities to enhance privacy.

2.1.2 Scientific problem

Privacy-Enhancing Technology (PET) research is receiving an increasing amount of attention in recent years. Research includes how privacy-by-design can be implemented from an engineering and legislative perspective (Domingo-Ferrer et al., 2014, p. iii), and from a big data perspective along with empowerment and control techniques (D' Acquisto et al., 2015, p. 5). Also a methodology to compare PET maturity has been researched (Hansen, Hoepman, Jensen, European Union, & European Network and Information Security Agency, 2015, p. 5). Besides this research which is more qualitative in nature, also quantitative research has been conducted to understand the economics of privacy and the choices consumers make (Jentzsch, Preibusch, & Harasser, 2012, p. 1).

In contrast to previous research, quantitative research to analyse drivers and barriers to PET adoption & diffusion has not yet been proposed while such research may give a valuable generalizable understanding on the matter of privacy innovation.

The value of such research is emphasized by the fact that operational privacy engineering is mainly focused on a technological discussion (Domingo-Ferrer et al., 2014, p. 52). Likewise, theoretical knowledge taught to students is of a technical nature. The selection of literature at two out of three technical universities in the Netherlands underlines this. Delft University of Technology and University of Twente have merged their expertise into the course Privacy-Enhancing Technologies. Out of the 25 mandatory readings in the course only one paper covered Privacy-Enhancing Technologies from a non-technical perspective, namely Domingo-Ferrer et al (2014). Technical solutions discussed include Tor, encryption, signatures, authentication, protocols and differential privacy databases.

However, technical solutions do not arise in isolation nor without non-technical restrictions. Factors such as the knowledge and innovation environment, design values, research and development practises, and economic viability shape the perimeters in which PET innovation takes place and its success is forged. From a commercial perspective, up to 47% of the pioneers that are first to introduce a product on the market fail and vanish (J. Roland Ortt, Zegveld, & Shah, 2007a). This failure rate is only considering the very first diffusion phase thus before considering the adaption phase of a technology and before the market stabilization phase (J. Roland Ortt, 2010). Neglecting core factors such as customer needs (e.g. usability) and economic viability (both to businesses and consumers alike) will likely hurt adoption and widespread diffusion of PETs (J. R. Ortt & Delgoshaie, 2008). Notably, all

these risks are important to consider before the battle for dominance starts in the stabilization phase. Neither a pioneer nor a first-mover is guaranteed dominance (J. Roland Ortt, Zegveld, & Shah, 2007b). And neither a superior model on which a product or service is based nor a technology of which most experts agree that it will become a dominant technology (Tanenbaum & Wetherall, 2011, p. 51) will guarantee the success of a PET product or service.

One of the major difficulties of a successful Privacy-Enhancing Technology product or service is the ability to be economically viable. Indeed, both in big organizations and small projects costs are involved with development which need to be covered. Privacy invasive business models can often easily offer the funds needed to cover costs. Consequently, in contrast to the privacy-enhancing business models, privacy invasive business models are prevalent. Personal data and behavioural profiling is the "gold" of a new category of companies that have found novel ways to monetize these personal data and behavioural profiles (Nissenbaum, 2004). For example, the largest data aggregators worldwide, including Google, Facebook, Apple, Amazon and Twitter provide their 'free' services by the rather opaque payment of citizen privacy which includes personal sensitive information (Devos, 2014) (Schneier, 2010). Particularly, CEO's of the biggest private data aggregators (e.g. Google and Facebook) seem not to be fond of privacy. They declared that the age of privacy is over and set privacy-unfriendly defaults for their users (Schneier, 2010). Also, since Google relies for 96% of its revenues (Bork & Sidak, 2012) (Securities and exchange commission, 2011) on advertisement, there is no incentive to empower users with Privacy-Enhancing Technologies as this would diminish revenues.

However, also from the demand side, the perspective of organizations (e.g. integrators) that should adopt Privacy-Enhancing Technologies to serve their customers, there is a tendency to give privacy a low priority. Especially important in this development, is the immense potential impact of digitization has started to emerge and accelerate in recent years. The reason for this is that the marginal costs associated with discovery, access and distribution of products and services is virtually zero. This results in the absence of entry barriers and the emergence of micro supply chains and micro multinationals that tap into global entrepreneurial opportunities. This puts a burden on both incumbent organizations and start-ups pushing them to innovate at an increasing pace. Consequently, organizations need to innovate their business models in novel ways (Manyika et al., 2014, p. 11). Indeed, this digitization trend exacerbates privacy infringement of citizens threefold. First, if an organization decides to give privacy protection a low priority, the risk of a privacy breach remains high. Second, if an organization disseminates information among other actors the risk of privacy being undermined increases due to discrepancies in operationalization of norms and values between organizations. Third, and finally, an organization may choose to monetize the private (meta) data or information to stay competitive, for example by selling privacy information to the highest bidder.

Also from an end user perspective, users of products and services may still opt for a more privacy-invasive product or service for reasons unrelated to privacy (Sloan & Warner, 2013, p. 335). However, users expose themselves to risks greater than potential privacy invasions. Indeed, while the protection of data integrity and the prevention of unauthorized access to information is part of information security procedures, whether this information is stored lawfully and with consent is not an integral part of such procedures (Devos, 2014). Hence, do we want to empower users with privacy-friendly options, a solution needs to come from organizations that value the creation and deployment of PETs that are designed with user privacy as part of the design, not as an afterthought.

Hence, there seems to exist the challenge of changing the status quo. Above all, for PETs to be effective privacy cannot be an afterthought because privacy norms and values are fundamental to its purpose. This counts for both producers of PETs, producers of services and products that use or integrate PETs, and the consumers that use PET enabled services and products.

In conclusion, quantitative research to analyse drivers and barriers to PET adoption & diffusion has not yet been proposed. However, a new understanding may arise that can sculpture future management decisions and policies. Privacy-Enhancing Technology producers have experience and knowledge on what is important in PETs. For these experiences and knowledge the factors that drive and impede PET innovation can be extracted in the form of a survey that is based on the privacy literature, management literature and interviews. This thesis aims for adding to the PET discussion from this new perspective to give organizations and policy makers a more profound understanding of what factors drive PET innovation and what factors impede PET innovation. The practical strategic goal of this thesis is to offer organizations and policy makers a deeper understanding of privacy innovation to improve the availability and quality of PETs, and for organizations to improve their business model that support sustained PET awareness, innovation and development.

2.2 Research objective

The research objective is to create a recommendation for technology producers, policy makers and communities that are involved in shaping the future of privacy aware technologies by identifying key factors that drive and inhibit the adoption and diffusion of Privacy-Enhancing Technologies in primarily (on-line) data communication and storage products and services. The research is focused on problem analysis because it is not fully clear why Privacy-Enhancing Technology adoption & diffusion is a problem and whose problem the adoption & diffusion of PETs precisely is. There is a gap between the current availability of Privacy-Enhancing Technologies and the desired situation in which Privacy-Enhancing Technologies are ubiquitous. Moreover, what general norms, values and ideals to use as a basis for Privacy-Enhancing Technologies is not transparent nor one overall accepted solution is agreed

upon (D' Acquisto et al., 2015, pp. 5–7) (Domingo-Ferrer et al., 2014, pp. iii–iv). The aim of this research is to give a more solid understanding about the adoption & diffusion of PETs.

The research consists of four steps which alternate between divergent (i.e. broaden the understanding of the topic) and convergent (i.e. filtering information and narrowing down in a concise manner).

The first step is divergent and consists of a qualitative input from interviews of privacy-focused actors to establish a questionnaire. The qualitative input used in this research comes from interviews done by Dr. Hadi Ashgari, assistant professor at Delft University of Technology of the section Cyber Security who is as well a visiting researcher at Princeton University of the section Center for Information Technology Policy (CITP) covering privacy related work.

Second, in a convergent step, the ENISA (European Union Agency for Network and Information Security) literature, Cyber Security literature and technology management literature will be used. This is done to find whether the issues from the interviews are of isolated urgency and importance, or are believed to be of broader significance. In the latter case an issue is deemed more interesting to this research. The issues will be formulated in a questionnaire that forms the basis for the quantitative results.

Third, in a divergent step, the quantitative results will be analysed and compared to establish what factors are important drivers and barriers to PET adoption & diffusion.

Fourth, as a final step, managerial implications are established as a convergent part of the research which transforms the abstract quantitative results back to specific and useable information and recommendations. The current literature is juxtaposed to affirm and note discrepancies to create an addition to the literature. Managerial and policy implications will be distilled from these results.

Research projects can be divided in categories (Verschuren & Doorewaard, 2010, p. 41,61-63). Taking into consideration the nature of the problem mentioned in subchapter 2.1 , while also being an *empirical quantitative* and *explorative*, a *practise-oriented* project is proposed. The reason for this is that the research is meant to provide knowledge and information that can be used to contribute to a better understanding and successful intervention. This should result in establishing a baseline to diagnose and change a current existing situation into a situation which is perceived as more favourable. Moreover, the *problem analysis* research type is fitting, because a problem analysis allows for gaining an overview of problems and successes concerning the challenges of developing Privacy-Enhancing Technologies. This thesis comprises of an additional Entrepreneurship Annotation part, which involves for example business (model) improvement. The definitive deliverable for the Entrepreneurship Annotation is translating the qualitative (based on Dr. Hadi Ashgari's work) and quantitative results into managerial implications that are stated in specific and practical concise recommendations. However, a natural step after problem analysis research is *diagnosis* research (Verschuren & Doorewaard, 2010, p. 41), which

the annotation work will not provide. Therefore, for the Entrepreneurship Annotation part is better included as an integral part of the whole thesis rather than an appendix-like work that would be separated from the thesis. The quantitative analysis will be used in relation to existing literature to elicit managerial implications and add to the literature.

2.3 Research framework

A research framework is used for extracting research questions from the research objective. The research framework allows for creating a sharper view on what insights and information can be used to achieve the research objective (Verschuren & Doorewaard, 2010, p. 56).

As shown in the previous sub chapter, the research objective shows the stages in which awareness is created, defines the extent of the project context that will be worked in, and what the contribution of the research will be towards the context. Ensuring that the research objective will be achieved is done by formulating research questions.

The research framework presents all parties involved and depicts the nature of the research project and the anticipated inputs and results. Also, the schematic representation of the research framework lowers the risk of misunderstandings and ambiguous agreements which simultaneously allows for a higher focus on selecting relevant literature and from what perspective to study the selected literature (Verschuren & Doorewaard, 2010, p. 82).

In broad lines the research framework consists of six phases covering the whole MSc thesis project and Entrepreneurship annotation. Of the six phases, three phases will result in an answer to the sub research questions (see the fields with blue background colour in phase b, d, and f of Figure 2).

The research phases are as follows (also see Figure 1 for schematic overview):

First (a), an analysis of the literature reveals necessary theory concerning Privacy, Privacy-Enhancing Technologies (PETs), adoption & diffusion of innovation and organizational structure including project management. Currently, the literature reveals that there is a poor understanding of PET adoption & diffusion. The aim is to create a conceptual model that describes the adoption & diffusion of PETs.

Second (b), a conceptual model of PET adoption & diffusion is established. The model forms the basis for creation of the questionnaire. The model will be complemented with the interviews of Dr. Hadi Asghari and review feedback of experts in the field of privacy, cyber security and innovation. Phase b holds the result of the conceptual model of what categories influences the adoption & diffusion of PETs. This conceptual model provides a basis for finding the drivers and barriers concerning adoption & diffusion of PETs.

Third, phase (c). Together with the output of phase (b) a questionnaire is created. The questionnaire is created iteratively, receiving feedback from the thesis advisors and experts. Experts requested to give their feedback include: innovation and economics of cyber security experts at the TU Delft, ENISA, and Dr. Phil Zimmerman (a well-known and well versed privacy advocate, currently associated with the TU Delft). To add to the academic literature, the questionnaire will consist of Wiki Surveys which allows for quantitative analyses due to structured questioning. However, Wiki Surveys allows respondents to answer in manners that break with the listed answers in the questionnaire when a strong desire exists to do so. Even though such alternative answers will add complexity to the analysis of the data, it may give unique and idiosyncratic results that may point in an unveiling direction.

Fourth (d), the results of the questionnaire will be analysed by descriptive statistics and Principal Component Analysis to reduce factors.

Sixth (e), the generated model, the interviews of Dr. Hadi Asghari and the literature are compared to find any striking, contrary or additional insights that may add to the academic literature. The model should reveal factors that form drivers and barriers to the adoption & diffusion of PETs. The model outcome together with current policy and management practises may result in an understanding of underlying reasons, opinions, and motivations concerning barriers and drivers of PET adoption & diffusion.

Seventh and finally (f), the quantitative results are used to perform diagnostic research and form specific policy and managerial implications. The results may even be applied to specific PET niches or organizations, depending on a good fit between PETs, organizations and significant findings. The aim is to give advice to support possible improvements and recommendations in an abstract, yet specific way. 'Abstract' here means that no *design research* is done on how found problems can be tackled, but only *diagnosis research* which entails finding causes, backgrounds and interrelated aspects of the problem (i.e. barriers that counter and drivers that advance PET adoption & diffusion) (Verschuren & Doorewaard, 2010, p. 95). The demarcation is made because of focus and time constraints.
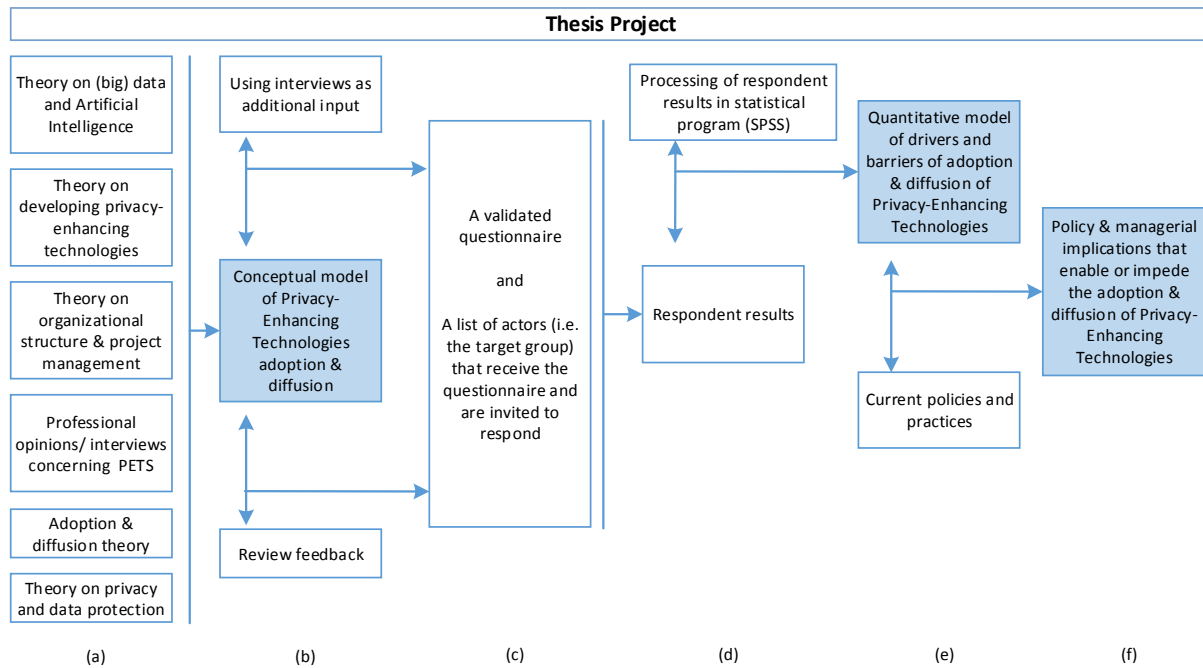
Figure 1 Research framework of thesis project; a blue filled field is shown for each research question.

The organizations that will be requested to respond to the questionnaire in phase (c) should be knowledgeable actors that produce PETs. While a broader group of respondents would result a higher response and more diverse views on the one hand, it will also make the quantitative result difficult to generalize to a certain group of actor on the other hand. For example, customers that are involved with PETs or are in another way affected by a lack or existence of PETs could be experts about the market needs (e.g. lead users). However, generalizing the results to both producers and users would be difficult.

Potential respondents include every actor of interest worldwide, because PETs are developed not only internationally, but also in joint, and even decentralized, multi-national teams. Moreover, PETS affect users and companies worldwide, even when an organization is centralized and developing in one country only.

Respondents may be retrieved from on-line PET overviews (i.e. lists with PET products and services). Also, professional privacy associations and word-of-mouth can be used. In addition a weblog will be created under the web address https://privacyinnovation.weblog.tudelft.nl/ to spread the questionnaire and allow interested parties to read more background information about the research. The questionnaire may be sent to Privacy-Enhancing Technology developers in, for example:

1. Non-profit organizations (e.g. Mozilla foundation)
2. Businesses (e.g. start-ups, Small and Medium-sized Enterprises, Corporations)
3. Small scale open-source projects

The actors affected by PETs will be a larger group than the group that will be invited to respond to the questionnaire. Nevertheless, the outcome of the research has a bearing on both producers, users and

integrators alike. For example, users' values are important to consider because those users will only adopt a PET if it fits their norms and values.

2.4 Research questions

The central research question is stated in order to establish the knowledge that is useful and necessary to achieve the research objective. The central question will be unravelled in three sub questions (Verschuren & Doorewaard, 2010, p. 91).

The central research question is:

"What factors are drivers and barriers to the adoption and diffusion of Privacy-Enhancing Technologies in private communication and data storage?"

The central question is supported by three sub questions. The phases that are spoken of in this chapter correspond with the phases mentioned in sub chapter 2.3 with the schematic representation of the phases shown in Figure 1.

Sub research question 1 (result in phase b):

"What relations can be found (i.e. what does the literature state) that describe Privacy-Enhancing Technology (PET) adoption & diffusion in an organizational (e.g. business, public or non-profit) setting?"

The first sub question will be answered with the help of three major steps. First, the literature will serve as a basis to comprehend the adoption & diffusion model of PETs. Second, interviews will serve as qualitative additions (e.g. whether some important and relevant issue is overlooked) to the literature findings. Third, expert review feedback will serve as another element of quality assurance. In addition, further insights can be based on the *snowball method* which means that starting gathering information with one person of interest leads to new knowledge on which the decision is based who to gather new or additional information from next (Verschuren & Doorewaard, 2010, p. 201). The gathering of information can be halted by the *exhaustive principle*, which means that if no new or additional information of apparent value is collected and it is improbable that new or additional information can be gathered by continuing contacting new individuals, that the search can be halted.

Sub research question 2 (result in phase e):

"What factors are the most influential drivers and barriers in the adoption and diffusion of Privacy-Enhancing Technologies (PETs) according to producers of PETs?"

The second sub question is of a theoretical nature to establish how the qualitative research of phase (a) can be embedded in knowledge that is currently available on the topic of adoption and diffusion of PETs.

The sub question will be answered by the results on a questionnaire. The questionnaire questions will be processed by Principle Component Analysis and Linear regression to find the barriers and drivers from a quantitative and analytical perspective.

Sub research question 3 (result in phase e):

> "What are policy and managerial implications of the found driver and barriers to the adoption and diffusion of Privacy-Enhancing Technologies?"

The third research question entails the practical interpretation of the results found in phase b. The results will be derived from the analysis in phase b and be communicated in a human understandable and practical sense.

2.5 Management and policy relevance

Understanding the diffusion process increases adoption of technologies and minimizes wasted efforts on failed market introduction (J. Roland Ortt, 2010). While literature is available on what factors are deemed important to improve adoption and diffusion (D' Acquisto et al., 2015) (Domingo-Ferrer et al., 2014) there has been made no efforts to model the adoption & diffusion of Privacy-Enhancing Technologies based on a sample of the PET developers community. This thesis tries to add to the research from this novel perspective which may result in a more profound understanding of what factors drive and impede PET adoption & diffusion.

Furthermore, cyber security receives increasing attention in the media. Both businesses and consumers are getting more aware of the issues around cyber security and how it may affect their privacy. Cyber security should be the biggest concern of 2017 (Cerrudo, 2017), says a professional hacker, cyber security researcher and CTO of IOActive Labs. Illustrated by the prediction that 200 billion devices will be connected to the Internet by 2020 (Intel, 2017) this emphasizes the importance of privacy when the omnipresence of devices and the data collected increases. To ensure privacy, this rapid growth requires legislative and policy changes to accommodate a world that becomes increasingly prudent to the weaponization of, for example, the Internet of Things (Sutherland, 2017).

However, the increasing need for Privacy-Enhancing products and services to guarantee privacy may also be seen as a competitive advantage to organizations. Consequently, organizations need to adjust their development processes, be able to attract the right skills, funding and partners to create Privacy-Enhancing Technologies that adhere to the users' values. Both from a policy and management perspective, the adoption and diffusion of PETs will result in gains from both a private perspective (e.g. commercial opportunities) and a public perspective (e.g. social benefits for our society at large due to increased privacy).

Especially from a policy perspective a case such as OpenSSL is interesting. While the world depends on OpenSSL only little funding was available. A streak of vulnerabilities was necessary before resources of government and business were pulled together because the whole world was suddenly at risk. In contrast, a PET developing ecosystem in which a myopic reactive attitude is traded for proactive policies that support Privacy-Enhancing Technology development, adoption & diffusion will structurally benefit privacy innovation and thus society at large.

2.6 Scientific contribution and deliverables

The major scientific contributions of this thesis are twofold. First, an aggregation of the literature and interviews result in a novel Privacy-Enhancing Technology adoption & diffusion model. The model serves as a template for the quantitative part of the thesis. Second, the quantitative part will form a novel basis for a conclusion that transforms quantitative results of the PET adoption & diffusion questionnaire to policy and managerial recommendations.

A minor addition to this research has been giving the respondents the possibility to speak their minds freely via an open question at the end of each section in the questionnaire. The open questions serve as contextual reference and feedback that may be of value for future research. The intention is to capture a richer content compared to a closed-ended questionnaire only.

3 Literature review

After having described the research design in the previous chapter, this chapter describes the literature review. This chapter focusses on available scientific literature and non-scientific sources to learn from previous work, state-of-the art knowledge and helps to define and scope the research in this thesis. This chapter is divided in three sub chapters. First, the relevant scientific research creates the context and defines concepts on which this thesis will be based. Second, a conceptual model that connects theory and concepts is given to highlight the connection between different sources and visualize the context. Third, a hypothesis is defined to give focus to the research.

3.1 Theory and concepts

This sub chapter explains the theory and concepts of adoption and diffusion, and the intertwined concepts of privacy and data protection.

3.1.1   Adoption and diffusion

Diffusion of innovation refers to the process by which an innovation is communicated among the members of a social system (e.g. the market for PETs) through certain channels over time (Rogers, 1983, p. 11). In contrast, the rate of adoption refers to the relative speed at which an innovation is adopted by members of a particular social system (e.g. the market) (Rogers, 1983, p. 23). When plotting the number of members (e.g. individuals or organizations) that adopt an innovation, the resulting graph has an S-curve. However, the literature is not consistent in making the distinction between the terminology of adoption and diffusion. Technology diffusion can be defined as the spread of a technology through a population (Schilling, 2012, p. 52) in which case diffusion is not about the communication but about the technology. Whereas the definition of adoption, namely the act of adopting a technology by a single member of a social system, seems to remain consistent among sources.

In this thesis diffusion comprises primarily the process of spreading (i.e. adoption) of Privacy-Enhancing Technologies through the market (i.e. a social system). Again, adoption is considered as an action by one member (e.g. a consumer or organization) of the social system. The social system is a contextual concept that may refer to the market for PETs of a country, another geographical demarcated region or even the whole world. Because PETs can be part of information systems that are globally interconnected a global scope is fitting.

3.1.2   Personal, private and sensitive data

Personal, private and sensitive data are erroneously often used interchangeably.

Personal data is defined in art. 4 (1) by the General Data Protection Regulation (GDPR) (Regulation (EU) 2016/679) as "any information relating to an identified or identifiable person" (European Union, 2016b, p. L 119/33). The concept of identification by reference, directly or indirectly, is quite broadly stated as "an identifier such as a name, an identification number, location data, an online identifier or to one or more factors specific to the physical, physiological, genetic, mental, economic, cultural or social identity of that natural person".

While personal data is a legal concept, the concept private data is not. Informally, it is synonymous with personal data. However, private data is rather a sub set of personal data in that it is the part of personal data that an individual does not want to make public. In essence all personal data can be private depending on contextual factors.

Sensitive data is defined as "special categories of personal data" in the General Data Protection Regulation (European Union, 2016b, p. L 119/2). Sensitive data should be subject to more stringent controls compared to personal data that is not sensitive. In a survey conducted via Salford Law School respondents classified for example political beliefs, health, medical records and legal/health/demographics information held by authorities and companies as sensitive data (Mc Cullagh, 2008). Additionally, the adjectives "sensitive" and "confidential" seem synonymous for "information that an individual explicitly chooses not to reveal of himself to the public" while also being labelled as special categories of information such as a social security number (Nissenbaum, 2004). This again emphasizes the need for additional controls.

In conclusion, personal data includes both private (i.e. data an individual wants to keep secret) and sensitive data (i.e. data that form a special category of personal data and should be subject to more stringent controls). Also, private data and sensitive data have a partial overlap: on the one hand data can either be exclusively private or sensitive and on the other hand data can be both private and sensitive. Above all, these subsets are part of the category personal data (see Figure 1, page 18).

This thesis uses the term private data to emphasize the part of personal data that individuals want to keep secret depending on the context. For example, the (extend of) information an individual shares differs between family members and the cashier of the local super market. In this thesis, the term private data can sometimes also be interpreted in a broad sense to include sensitive data, especially when more stringent controls are deemed appropriate.

3.1.3   Metadata

Metadata is different from data itself. However, metadata can still be both private and sensitive. Metadata is data that provides information about other data. Examples of metadata are descriptive metadata, administrative metadata and structural metadata (Riley, 2017, p. 6). Descriptive metadata can be used to find and understand a resource (i.e. certain data). Administrative metadata can be used for

technical reasons (e.g. decoding data) or preservation (e.g. long-term management of data). Structural metadata helps to define relationships of parts of resources in relation to one another.

Especially intelligence agencies try to diminish concerns about metadata retrieval. In their views metadata does not reveal the content of e.g. phone calls, messaging and e-mail.

In 2013 a classified court order to hand over telephony metadata to the NSA and FBI was leaked before its intended declassification in 2038. Concerns arose when it became clear that information such as session-identifying information, trunk identifier, telephone calling card numbers, and time and duration of call, would be handed over to the NSA and FBI (United States Foreign Intelligence Surveillance Court, 2013). James R. Clapper, Director of National Intelligence, commented that "The program does not allow the government to listen in on anyone's phone calls, and the information acquired does not include the content of any communications or the identity of any subscriber" (Ribeiro, 2013). Similar concern about privacy arose when WhatsApp decided to collect metadata, while the calls themselves are end-to-end encrypted.

Besides the discussion that the Patriot act in the United States may be overly broad interpreted by intelligence agencies (Cohn & Rumold, 2013) why bother with concerns about metadata? An illustration of the importance of metadata in relation to the actual private and/or sensitive data itself (e.g. a phone call or instant message) can be given via three examples (Opsahl, 2013). These examples show that metadata does in fact reveal the content of the message itself:

1. Intelligence agencies know you called the suicide prevention hotline from the Golden Gate Bridge. However, they will claim the topic of the call remains a secret.
2. Intelligence agencies know you spoke with an HIV testing service, then your doctor, then your health insurance company in the same hour. However, they claim they don't know what was discussed.
3. Intelligence agencies know you rang a phone sex service at 2:24 am and spoke for 18 minutes. However, they claim they don't know what you talked about.

When such information, as presented in the examples, is leaked it could have an impact on individuals' lives. When organizations intentionally decide to pursue the collection of metadata (i.e. refrain from data minimization), they do not develop Privacy-Enhancing Technologies as meant in this thesis.

In conclusion, metadata is able to present the context of the private data itself. Therefore, metadata can be classified as private data as well. In the discussion of Privacy-Enhancing Technologies, a true PET refrains from collecting metadata and thus pursues data minimization. Because of this, companies like Google and Facebook cannot give any meaningful response to the questionnaire and are excluded.

The relation between personal, private, sensitive and metadata can be viewed schematically in Figure 1. Data may be exclusively private or personal on the one hand, but can be both private and sensitive as well. The same counts for metadata. All such information is personal data as it relates to a person.
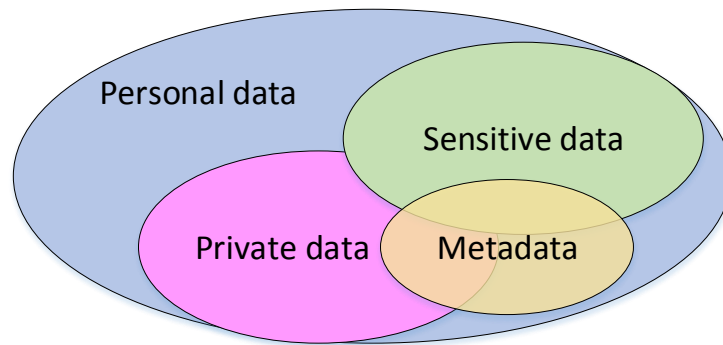
Figure 1 The relation between personal, private, sensitive and metadata; adapted from (Mc Cullagh, 2008)

3.1.4 The importance of privacy and data protection

Privacy and data protection (or "data security") are used interchangeably by many decision makers (Domingo-Ferrer et al., 2014). However, even though privacy and data security are intimately linked (Burmester, Desmedt, Wright, & Yasinsac, 2002) they do not have an identical meaning. For example, the thirty pages long International Standard for Information Security, ISO/IEC 27001:2013, describes information security management and mentions 'security' many times, but 'privacy' is mentioned only once. This section describes what privacy entails and demarcates the importance of Privacy-Enhancing Technologies.

The working definition in this thesis of "data security" is a composite of different definitions in the literature. Data security is the science and technological application of protecting data in computer and communication systems from unauthorized disclosure, from destructive forces and from unwanted actions of unauthorized users (Denning, 1982, p. v) (Kumar, 2014, p. 293). In addition, the General Data Protection Regulation (European Union, 2016b) defines data security as being part of the broader scope data protection. The scope of this thesis lies with innovation of data security. Nevertheless, data security will be viewed in the broader context of data protection in this thesis.

Additionally, a distinction between physical and logical security can be made. Physical security is placing a tangible barrier around a computing system to deter unauthorized physical access to the computing system itself. In contrast, logical security are mechanisms by which operating systems and software running on an operating system prevent unauthorized access to data. Logical security consists of software safeguards which may include authentication, authorization and encryption (Koç, Paar, & CHES, 2000, p. 302). This thesis focuses on logical security. The reason for this focus is the issue of network externalities (Schilling, 2012, p. 67). Because of the lack of an infrastructure and the necessity for both ends of a communication channel needing the same physical security, to ensure interoperability, physical security innovation would diminish the adoption rate of a PET innovation in a rapidly changing technological landscape. Innovation consisting of physical security would take a multiple of time needed compared to logical security. This thesis focuses on innovation opportunities in the near future, rather

than the more distant future, because PETs focussing on logical security can be easily distributed through an established infrastructure, namely the Internet.

Another concept to consider is privacy. Privacy is considered to be a vague concept and is often defined through people's fears and anxieties. Especially *information privacy* is considered to be a significantly vaster and more complex concept than the collection of torts to the constitutional "right to privacy" (Solove, 2006). However, well-reasoned taxonomies have been established in recent years which assert that privacy is contextual and should be seen in relation to societal norms and values (Nissenbaum, 2004) (Solove, 2006). Moreover, privacy should not be seen as an immutable possession of individuals, but rather in the light of "the contribution they make to the welfare of the community" (Solove, 2006). Above all, privacy harms impede activities of individuals that contribute to the greater social good. Therefore, privacy is not an external restraint on society, but rather an internal dimension of society (Solove, 2007).

Privacy can potentially be scoped in a wide-range extending over communication, decisions, thoughts, activities and information. However, due to keeping the research in this thesis practical the aim of privacy is limited to the *right of privacy* as it applies to information about individuals.

Three prevailing principles dominate public deliberation surrounding contemporary privacy (Nissenbaum, 2004). The three principles are concerned with: (1) restricting access to personal, private or sensitive information, (2) limiting surveillance of individuals and the use of collected information about them by government actors, and (3) diminish intrusions into places that are deemed personal or private. The context of PET innovation research will follow the path of public deliberation while remaining sensitive for interesting crossroads (e.g. from the interviews) that can add to the interpretation of privacy. Besides public deliberation, jurisprudence emphasizes that individuals also need to (1) exhibit behaviour that support their expectation for privacy on the one hand, while (2) the expectation must be considered reasonable by society on the other hand (Katz v. Unites States, 1967). An example of unreasonable expectations of privacy is expecting others not to see, notice or make use of information acquired in a public place, because this would be unreasonably restrictive of other individuals' their freedoms.

Almost everything that individuals do, either individually or collectively, happens in a context of cultural expectations. Notably, culture is defined as "rules of the social game" as set of arbitrarily defined social conventions (Hofstede, Hofstede, & Minkov, 2010, p. 26). From a cultural standpoint, privacy is governed by norms of appropriateness, and norms of information flow or distribution (Nissenbaum, 2004).

Norms of appropriateness dictate what information about an individual is appropriate to reveal in a specific context. Indeed, such norms delineate and demarcate what type of information about what individual, within a given context, under what circumstances is allowed, expected, or even demanded

to be revealed. As an example: a patient shares his medical condition with a physician, while a physician would typically not share his health status with the patient. Moreover, a patient normally would not share this exact same health information with his lawyer.

Norms of flow (or distribution) of information relates to the transfer of information from one individual or group to another individual or group. In particular it is worth noting that different groups of individuals (i.e. social spheres) have different norms, which have different perceptions and conventions on what norms of flow of information are appropriate. As an example, a physician may not be inclined to share a patient's information to a lawyer. However, when the physician and lawyer are good friends, the physician may be inclined to make an anecdotal reference to a patient's personal story.

Norms can also be a complex cascade. For example, in the United States laws stipulate when and in what context a physician is bound by a patient's consent. Whenever a condition poses a public health risk, the physician is allowed to use a different set of norms than the set of norms used for mere diagnosis and treatment.

For this thesis relevant informational norms imposing *restrictions on the flow and distribution of personal information* are (Nissenbaum, 2004):

1. Prevention of information-based harm
2. Informational inequality
3. Autonomy
4. Freedom
5. Preservation of important human relations
6. Democracy and other social values

In contrast, relevant informational norms that *support free or unconstraint flows of information* considered in this thesis are (Nissenbaum, 2004):

1. Freedom of speech
2. Pursuit of wealth
3. Efficiency
4. Security

For this thesis relevant groups of potential harmful activities are (Solove, 2006) listed below. This thesis expands the term 'information collection' in 'private data', 'tracking data', 'meta data' and 'public data'. The necessity of this division in data types is to allow for a more precise delineation of core issues in discussions. These data types have been distilled from the interviews.

1. **Information collection**, the collection of information by "data holders"
   a. *Private data*, data that is kept from publication by the owner
   b. *Tracking data*, data gathered during using the Internet about a user, e.g. browser brand and version, and screen resolution
   c. *Meta data*, data about data, e.g. at what time there was a call with who
   d. *Behavioural data*, data that reproduces human behaviour, e.g. browsing history

e. *Public data*, data publically available about individuals and other entities
2. **Information processing**, store, combine, manipulate, search and use information
3. **Information dissemination**, transfer of information to others or the release of information
4. **Invasion**, invasion into an individual's private affairs; encroaching directed towards an individual that does not necessarily involve information.

In conclusion, privacy and data protection are considered separate concepts. Data security (or "data protection") is the protection against unauthorized disclosure, from destructive forces and from unwanted actions of unauthorized users. Privacy is the control to reveal information about oneself at own discretion depending on contextual factors, i.e. how individuals want to present themselves to the world. Individuals have the right to be protected via restrictions on the flow and distribution of personal information, e.g. to protect freedom, autonomy, etc. At the same time individuals must have the ability to feel supported to have e.g. freedom of speech (the unconstraint flow of information). Possible actions that can be taken in relation to information are information collection, information processing, information dissemination and invasion. The latter, invasion, does not necessarily involve information directly while it could serve as a means to extract information.

3.1.5   Privacy-Enhancing Technology definition

Privacy-Enhancing Technology (PET) is a fuzzy concept in practise (Hansen et al., 2015, p. 9). Privacy-Enhancing Technologies are sometimes referred to as Privacy-Preserving[1]. A narrow definition of Privacy-Enhancing Technologies could include only attributes such as data minimization and privacy-by-design. However, for this research this would mean that the demarcation of what technologies to label as PETs becomes difficult due to a lack of specific parameters.

The working definition in this thesis is that Privacy-Enhancing Technologies include products and services produced by organizations and projects that focus on privacy preserving, respecting and enhancing technologies. This entails giving users more control over their data, personal identifiable information and metadata. Organizations and projects for this case include for example Nextcloud, Protonmail, OpenSSH and Tor.

In contrast, organizations storing, analysing or sharing personal data, information and/or metadata with the goal of monetizing, having unclear purposes not serving users' privacy and/or sharing with intelligence agencies are not of interest to this research. This contrasting case includes for example Facebook and Google.

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[1] https://www.google.com/patents/US8868654

3.2 Conceptual framework

This sub chapter will elaborate on the conceptual framework. The distinction between privacy business models is described. Next, the comprehensive engineering and how entrepreneurship fits into this is explained. Finally, the Privacy-Enhancing Technology adoption and diffusion framework and model is presented.

3.2.1 Privacy business model

This section allows for understanding where PET producing organizations should be positioned and how they relate to other kinds of organizations.

Privacy-invasive business models are already well-established (Domingo-Ferrer et al., 2014, p. 51). Equally important is that the business models of organizations rely for an increasing portion on private data itself (Devos, 2014). Hence, a trend of increasing privacy-invasive business models is on a rise. Examples of companies that heavily rely on the use of private data are Google and Facebook. Google revenues rely for 96% (Bork & Sidak, 2012) (Securities and exchange commission, 2011) on advertisement which uses behavioural data to tailor advertisements to users (Federal Trade Commission, 2010). In stark contrast, organizations that produce Privacy-Enhancing Technologies that respect privacy by not using behavioural data, employ an opposing business model (i.e. data minimization). Such Privacy-Enhancing Technology organizations monetize privacy by *guaranteeing information privacy* instead of *using private information itself*. In essence, their product is safeguarding user privacy instead of harming user privacy.

Besides for-profit organizations, there are also actors that do not monetize privacy or minimize such activities. Such organizations include the government and non-profit organizations. The value of private information for such actors is not focussed on monetizing privacy but covering expenses. Likewise, for-profit organizations may also use private information to optimize business models and to mitigate risk. This last example shows that organizations use private data to understand how a product or service is used by its customers in order to improve the product or service without monetizing on the private data itself (Kaplan & Norton, 2001).

In this thesis an explicit difference exists between Privacy-Enhancing Technology organizations that monetize by guaranteeing privacy (i.e. by a lack of user data retention and giving users control over their privacy) and organizations that use private data itself (i.e. high data gathering and retention giving users little or no control over their privacy) as a monetizing strategy. A schematic representation of privacy business model opportunities is given in Figure 2.

An explanation of every category (denoted by a number from 1 to 13) is given below. Figure 2 is not exhaustive, meaning that not every conceivable type of organization is noted individually. The purpose

of the figure is to understand the landscape of privacy invasive versus privacy monetizing on the one hand and what the scope of this thesis should exactly be on the other hand.

1. **For-profit PETs** are often proprietary PETs that are produced by companies (e.g. Sophos, Symantec and Trend Micro). The purpose of a for-profit PET organization is to make a profit and often does so through novelty, lock-in, complementarity, and efficiency (Amit & Zott, 2001).

2. **Freemium PETs** are a category of PETs that are produced by for-profit organizations but have a high level of transparency. This category of organizations are characterized by often producing open source software and/or giving customers transparency about the architecture and infrastructure of the product or services that is delivered. Examples are organizations that offer file hosting, email and VPN services (e.g. Nextcloud, Protonmail and CyberGhost VPN). Such services are free of charge for small scale usage. However, when a user desires additional features, storage, speed and/or service a premium needs to be paid to receive such benefits. Although freemium PETs are created with a for-profit mindset the products or services are offered for free when used privately on small scale.

3. **Non-profit PETs** are PETs that are funded from a non-profit organization. Many products or services with security, autonomy and/or privacy in mind can be produced that have the added benefit of strong interoperability (e.g. Mozilla Foundation). Non-profit PETs are created to benefit the world as a whole while covering expenses.

4. **Free and Open-source (FOSS) PETs** Free and Open-source Software is created by individuals and communities of dedicated contributors. The contributors offer their spare time to add value in the form of an open source project. Such software can be used and forked (i.e. make changes to the code as you desire and redistribute) freely. FOSS PETs do not have any commercial strategies in mind (e.g. OpenSSH and The Onion Network). However, the sole purpose to produce FOSS PETs is the pursuit of technological superiority.

5. **Quadrant of *high* to *medium* privacy invasiveness and *medium* to *high* privacy monetizing**. This quadrant contains organizations that earn high profits from privacy monetization due to high privacy invasion. Organizations include big multinationals and cyber criminals aiming for high profits without respecting privacy.

6. **Quadrant of *medium* to *high* privacy invasiveness and *low* to *medium* privacy monetizing**. This quadrant contains organizations employ potentially high privacy invasive practices. However, their goal is not to monetize privacy. Instead, the value of private data is to ensure national security (e.g. NSA, CIA), extort (e.g. Anonymous) or merely allow society to function (e.g. legislative government, local government).

7. **Business model optimizing and risk mitigation** is an example of using private data to improve business models and mitigate risk without the purpose of monetizing private date. The invasiveness of privacy range from low to high. Because of this the category is shown on the centre of the Privacy invasive x-axis.

8. **Data brokers** are the most privacy invasive actors that exist to date especially because they structurally expand their private data collection while operating as a legitimate business. It is known that over 220 "data elements" in twelve "segments" are collected by data brokers. Segments include: identifying data, sensitive identifying data, demographics data, count and

public record data, social media and technology data, home and neighbourhood data, general interest data, financial data, vehicle data, travel data, purchase behaviour data, and health data (Ramirez, Brill, & Ohlhausen, 2014, pp. B3–B6).

9. **Social profilers** harvest and sell personal data that is mostly voluntarily shared via social media. However, not all data is voluntarily procured and companies (e.g. Facebook) even mislead governments about privacy concerns such as matching private data between platforms (Rankin, 2017). Social profiling and selling the data is often done by large multinational social media companies, data storage services and search engines (e.g. Dropbox, Twitter, Facebook and Google). These companies focus their efforts on acquiring a maximum amount of private data which is then sold to other parties (Federal Trade Commission, 2010). This category is positioned above "For-profit hackers" because big multinationals have structural capabilities to harvest and sell private data. In contrast, for-profit hackers often have access to private data for a shorter timeframe (e.g. when bots are disinfected or a Botnet Command & Control node is shutdown).

10. **Malware** is any software with malicious intent (e.g. Ransomware, Spyware, Trojans, Worms and Adware). While still being very privacy invasive and scoring high on privacy monetizing, access to and monetizing from private data occurs typically for a smaller duration than for harvesting and selling personal data

11. **Legislative government** (e.g. Congress) have a need for private information to identify citizens. Examples of the necessity for private information is Personally Identifiable Information (PII) that is needed to create a passport. The government asks a fee to cover the cost of the document. While individuals know that their PII is stored with the government it is not always known what the government does to enrich this data. There are instances where the government breaks their own laws to acquire private information such as abusing highway camera's (Feteris & Koopman, 2017). The legislative government is one of the three state powers (trias politica).

12. **Idealist hackers/ groups** (e.g. Anonymous) are groups of individuals that fight for moral causes through cyber-attacks. They gather privacy invasive information to force or extort an individual to act as demanded by the idealist hacker group. While actions of idealist hackers is highly privacy invasive, their intention is not to monetize the acquired private information. Because the information gathering practices are more invasive than that of the legislative government but less invasive than that of intelligence agencies this category is placed in between on the x-axis.

13. **Executive government** is one of the three state powers (trias politica). The executive government executes whatever laws are passed by the legislative government. Agencies of particular interest are the intelligence agencies. Intelligence agencies (e.g. NSA, FBI and GCHQ) often outstep their bounds as became painfully clear after the Edward Snowden revelations in 2013 but also in recent years (Wilson, 2015). A notable property of government agencies is that they have considerable resources. While their practices are highly privacy invasive, the focus lies with protecting the state they work for; the focus does not lie with monetizing the private information.

Figure 2 is not exhaustive. For example, other groups that could be defined in the quadrants are possible. An example is the group of semi-governmental actors (otherwise known as State-owned Enterprises (SOE)). Especially in the health care sector are many instances of privacy invasive practices. However, to overcome this shortcoming areas designated with a 5 and 6 depict the kind of organizations that should reside in these areas.
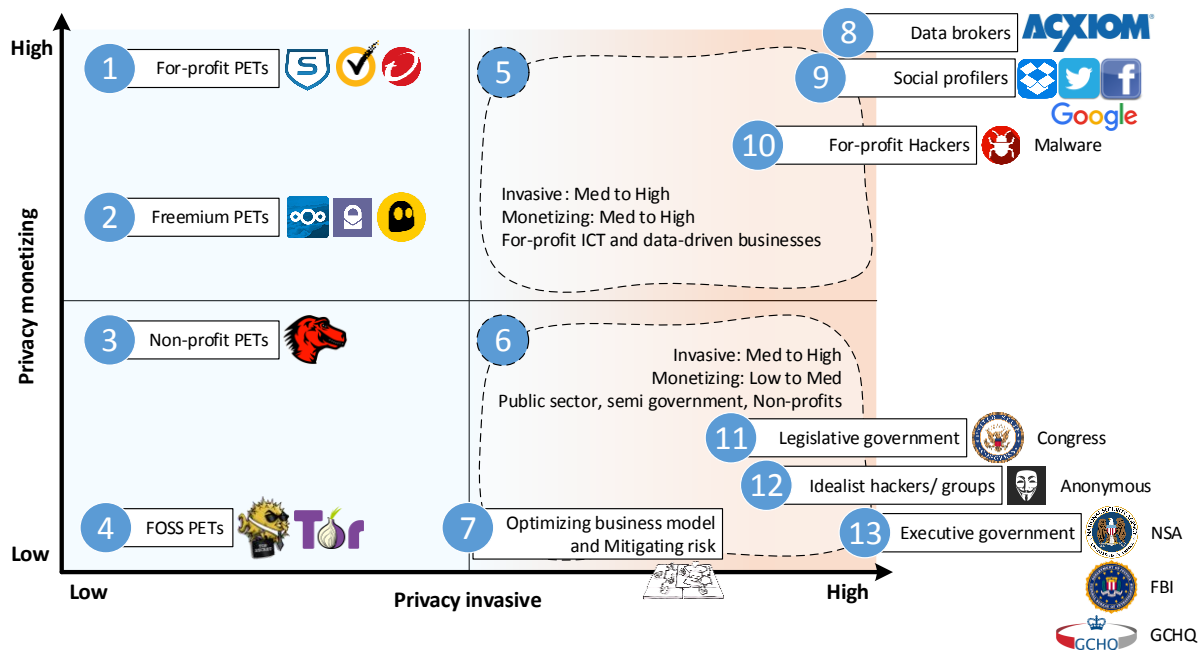

Figure 2 Privacy monetizing (e.g. free, for-profit) versus privacy invasive activities (e.g. selling user private data). Positioning should be seen relative to one another and aims at showing the landscape rather than the exact relations between actors.

While all of the mentioned actors in Figure 2 can create PETs, the unit of analysis are the PET producing organizations with a low privacy invasion (i.e. the far left on the x-axis). Moreover, because cloud services rely on PETs to deliver privacy in their product/service, and cloud services are used at an increasing rate, privacy respecting cloud products/services (e.g. Nextcloud) are included in the unit of analysis as well.

3.2.2 Comprehensive Engineering and entrepreneurship

Besides functional requirements, new technologies need to satisfy societal, moral and legal requirements as well. Traditionally, software engineers have not been trained to incorporate such non-functional requirements in their designs. Apart from non-functional requirements such as performance requirements (e.g. timing, speeds and throughput), software engineers often fail to consider specific quality requirements (e.g. security, reliability and usability) or constraints (e.g. legal, cultural) of a system (Glinz, 2007) (Chung & do Prado Leite, 2009). This failure does not necessarily mean that considerations are consciously waived. Instead, software engineers traditionally have not been trained,

nor are inclined to take responsibility, to consider certain types of non-functional requirements such as security, societal, moral and legal requirement (Axelrod, 2012, p. 48). Nevertheless, both usability and usefulness of a product or service depend on these non-functional attributes (Naveda & Seidman, 2013, p. 57). Non-functional requirements are typically normative in nature (e.g. a system should respect privacy in a certain manner, and security should have an availability of 99.8% during a year). The importance of involving ethics and a socio-technical perspective in engineering could be named comprehensive engineering (van den Hoven, 2016).

Comprehensive Engineering is a multi-disciplinary paradigm introduced at the faculty of Technology, Policy and Management of Delft University of Technology that merges different fields of science to obtain overarching solutions (Delft University of Technology, 2016). The focus lies with complex interconnected systems. Based on the concept of comprehensive engineering, the focus in this thesis lies with four dimensions: governance, technology, values and entrepreneurship. This introduces the dimension entrepreneurship.

Appropriate **governance** requires strategies and information that lead to better alignment of actors and business operations (Chun & Mooney, 2009), better decision making and better designs. The challenge of governance is to solve complex problems with conflicting interests of actors that are interconnected in a decentralized, non-hierarchical world.

Technological innovation often requires integration into existing infrastructures. In todays interconnected world technologies and ICT services continuously converge in complex engineering systems (van den Hoven, 2016).

Concerning **values**, the creation of novel technologies requires the assessment of ethical and social implications. Moreover, the effect of decisions should be considered on how a technology can be utilized by different users in the light of (conflicting) moral values. These issues should be intertwined in the innovation process and considered by engineers besides being able to carry out their work competently and skillfully (Poel & Royakkers, 2011, pp. 1–2, 38–39).

Entrepreneurship can be defined as the exploitation of new opportunities for value creation (Amit & Zott, 2001), and is concerned with what value is provided to customers and how a profit could be made in the process (El Sawy & Pereira, 2013, p. 25). Entrepreneurship is typically concerned with what, when and where this value for customers is made and how (i.e. via what channels) it is distributed (Osterwalder & Pigneur, 2013, pp. 18–41). Although it is said that this is the core source of sustainable advantage in companies today (Morris, Kuratko, & Covin, 2010, p. 3), the inspiring question of *why* an organization does what it does is the paramount question to convey to customers and stakeholders alike. It is the why question that drives both personnel, innovators and early adopters to participate in and to contribute to a vision through intrinsic motivation (Sinek, 2009). The pursuit of value in monetary terms to increase business sustainability, the inspiring aspect and the focus on commercial exploitation of new

opportunities for value creation is what defines entrepreneurship. In stark contrast, we can define governance as the process or act of exerting authority and/or control focussed on monitoring and mitigating risk (Schilling, 2012, p. 167), rather than taking risks, pursuing opportunities and inspiring customers and stakeholders. Indeed, governance is focused on formalization (e.g. rules and procedures) and standardization (e.g. predictable outcomes), while entrepreneurship is focused on, for example, breaking with incumbent practises and finding novel ways of doing business, improve the business model, find radical technological solutions or pursue creative recombination (Levinthal, 1998) to create competitive advantage.

Moreover, this thesis argues that entrepreneurship involves both exploiting own capabilities for commercial success and leveraging them in strategic alliances for strategic purposes such as pooling resources (Schilling, 2012, p. 158). Indeed, entrepreneurship is not a "we versus them" mind-set, but rather the pursuit of finding synergetic solutions both from an inter- and intra-organizational perspective. It is especially continuous entrepreneurship that leads to business sustainability which contrasts the Icarus Paradox (i.e. a firm resting on its laurels because of prior success which hinders its ability to respond to new technological or business developments) (Schilling, 2012, p. 209).

Indeed, only when an organization has an entrepreneurial mind-set and pursues business sustainability it can have a lasting effect on technological innovation, governance and the upholding of values. In the case of business sustainability the importance of economic sustainability (i.e. financial stability such as profitability, liquidity and solvency) and social sustainability (i.e. the company's impact on social systems) are paramount to be considered as a part of business objectives. For the Privacy-Enhancing Technologies innovation context the entrepreneurial dimension is an integral part of the three aforementioned dimensions. The appropriate balance between dimensions should include entrepreneurship or will lead to an incomplete overview of drivers and barriers if omitted. Therefore the concept is expanded by a fourth dimension which will be named "entrepreneurship".

3.2.3   PET adoption & diffusion framework

Five categories have been established based on the Privacy-Enhancing Technology literature, the literature on data privacy and privacy design, the interviews about Privacy-Enhancing Technologies and the technology management literature. These categories form a framework of what is deemed important to the barriers and drivers of innovation and development of Privacy-Enhancing Technologies. A total of five categories are divided in one dependent category (i.e. holding the dependent variables) and four independent categories (i.e. holding the independent variables). The five categories that will be used are organized as follows:

Category A: Adoption & diffusion of innovation

The category *Adoption and diffusion* is the aggregate of governance, technology, values and entrepreneurship elements. Adoption is the act of adopting an innovation by individual members in a social system (e.g. people or organizations). Diffusion is the process of spreading of Privacy-Enhancing Technologies through the market. The greater the adoption of a new technology the greater the diffusion and thus the greater the market share of the new technology. The technology may be part of either a product or service. Furthermore, the diffusion of innovation can be positively or negatively influenced by commercialization strategies (J. Roland Ortt, Zegveld, & Shah, 2007), linking this factor to the factor business viability & sustainability of PET producing organizations. Issues that may affect the diffusion of PETs include the importance of user-friendliness (e.g. in user interface design), interoperability and backward compatibility with legacy systems (e.g. old protocols or infrastructures). The importance of this category can be stated via the notion of the technology lifecycle (Hansen et al., 2015, p. 11). In a limited amount of time a technology needs to be adopted and diffused, while competing with other technologies or with the status quo (Venkatesh, Morris, Davis, & Davis, 2003). By competing with the status quo is meant that users of PETs need to perceive the usefulness and ease of use and change their attitude from their current behaviour (i.e. not using a PET) towards a new behaviour (i.e. using a PET). Especially for organizations (in contrast to consumers) PETs should align (Chan & Reich, 2007, p. 300) with the organization itself in the sense that a PET should support the business goals and vice versa.

Category B: Business viability & sustainability

The category *Business viability & sustainability* primarily revolves around entrepreneurship and governance. Business viability and sustainability is the initial feasibility of an organization and the financial safeguarding of continuity and retaining competitiveness. In other words, the ability to acquiring enough funds (e.g. through sales, funders and/or public support) to continue business operations and satisfying financial obligations. For products and services to respect user privacy it is important that a business model does not monetize private data. The business sustainability must come from a competitive advantage while at the same time safeguarding the privacy of its users. However, products and services have to compete with well-established privacy-invasive business models (e.g. personal data of users is harvested by offering the service for "free"; a user thus pays with his privacy). Privacy-respecting business models have to be sought (Domingo-Ferrer et al., 2014, p. 51).This factor is deemed important because the very existence of a company depends on it.

Category C: Knowledge and innovation environment

The category *Knowledge and innovation environment* is a difficult category because it shares dimensions with Design Values and Technology. However, the issues in this category need to be seen in the context of collaborative governance and the ability to share and produce data, information and knowledge about technology. For example, the proximity of university laboratories and research centres

to PET developing and researching organizations ensures access to scientific expertise. At the same time research centres and PET developing and researching organizations help universities to implement scientific discoveries in commercial applications. The result is a rise of self-reinforcing and long-lasting advantages (Schilling, 2012, p. 31). This does touch upon competitive advantage, like in the category *Business viability & sustainability*. However, the advantage here is meant in an inter-organizational context instead of intra-organizational, or as collaboration between organizations.

Indeed, organizations can explore and exploit their own competences or they can (in part) collaborate with other organizations. The latter could lead to a synergy in the form of pooling resources and knowledge which in turn may lead to an increased installed base or competitive advantage. For example, a PET developing organization could collaboratively increase privacy by focussing on a standardized PET product or service to increase the privacy of all their users (Domingo-Ferrer et al., 2014, p. 30). This kind of collaboration means that an organization can focus on its core competencies, leaving the PET innovation and development to the PET organization while being part of the development of a PET to fit specific needs. Collaboration is a reciprocal activity which should lead to mutual benefits in the short- and/or long-term.

Furthermore, the access to capital and laws that stimulate rather than impedes innovation are important as well. An example is the explicit protection of the privacy of European citizens via regulations (European Union, 2016a) and active research on Privacy-Enhancing Technologies (Domingo-Ferrer et al., 2014) (D' Acquisto et al., 2015) (Hansen et al., 2015). A favourable environment drives PET innovation rather than impede it.

Category D: Design values

The category *Design values* includes most prominently values. Especially with Privacy-Enhancing Technologies, the product or service **is** the operationalization of values. Besides values, also norms are important to consider because norms operationalize the underlying values through rules that prescribe what actions are permitted, forbidden or required (Poel & Royakkers, 2011, p. 74,335). However, this does not mean norms are more valuable than values, as it is not the intention to define what means (i.e. specific norms) are important for PET innovation but what values (i.e. global ends) underlie those norms (Poel & Royakkers, 2011, p. 74). While users have values of their own, legislators and standardization bodies expect that their standards are adhered to (Domingo-Ferrer et al., 2014, p. 53). We believe that if standards are not perceived to be compatible with the social factors (Venkatesh et al., 2003) that a user is subjected to in his or her culture that acceptance of a PET will be low (and thus the *adoption and diffusion*). Challenges include design trade-offs that can be operationalized as the ease of use and compatibility of a PET (Venkatesh et al., 2003). Ethical decisions need to be made that define how the product or service should behave in a certain context. Dilemma's such as from which perspective for what user should an ethical design decision be made? Could a function be abused and could this abuse

be countered or should it be accepted? Furthermore, the importance of this dimension relies on the extent to which a user believes that a PET can enhance the performance of his or her job (Venkatesh et al., 2003).

Category E: Research & Development of PETs

The *Research & development* category mainly revolves around technology and governance. The research & development of PETs focusses on software development and the challenges of software technology development. Challenges include complex issues between project management, alignment of employee skills with the organization and the reliance on necessary IT components. Furthermore, how research & development is executed in relation to users plays an important role in PET creation. It is considered better to be transparent in research and development opposed to confidential and be community driven while being independent from interests of a single stakeholder (Hansen et al., 2015, p. 36,44). Furthermore, the absorptive capacity (Schilling, 2012, p. 28) of an organization forms an important issue in research & development because the ability to assimilate and utilize externally obtained information as an advantage into the product or service is key to strategic success of PETs.

Considered as a part of Research & Development of PETs is leadership. While innovation is a creative process, innovation can be managed and stimulated (Cooper, 1990a). Also, creativity can be stimulated, for example by the right team or organizational structure such as an organic structure (Schilling, 2012, p. 212). Especially for PETs, where there is a tension between innovation and design values concerning privacy (see category *Design values*) on the one hand, and the need to monetize to guarantee business sustainability (see category *Business viability & sustainability*) on the other hand, make organizational leadership with the development of the PET product/service itself important. A good leader is able to balance decisions between the company, its employee's desires and customer interests. Pro-active initiatives that support the business' mission and vision beyond the company itself are also a clear sign of leadership. For example, initiatives to accelerate PET innovation does not necessarily need to be top-down. For example, input may arise bottom-up through an on-line PET development platform. In addition, a company like CyberGhost shows that a self-financed accelerator program that support start-ups with novel ideas is economically viable (Lomas, 2015). This is a typical example of bottom-up leadership which drives PET innovation. Also, CEO Robert Knapp of VPN service CyberGhost shows (based on an interview) his leadership as a privacy-advocate by respecting the no-logging norm while the need for user statistics to improve the service is important to business sustainability.

3.2.4 PET adoption & diffusion model

The five categories (described in section 3.2.3 are displayed in Figure 3. The rationale of relations (denoted with prefix 'R') between constructs (denoted with capital letter A to E) is succinctly described in

Table 1. The rationale is not exhaustive as many reasons for the relations can be given. However, the examples serve as a form of clarifying the context in which the relation is meant. The hypotheses that will be extracted from the model (denoted with prefix 'H') are represented in sub chapter "4.3 Hypotheses" (the next chapter) on page 36.

It is important to note that the model in Figure 3 is a simplified version for easy understanding. The model includes only the relations that will be used to base the hypotheses on. For a full model, including all the relations, please read "Appendix H: Full PET adoption & diffusion model" on page 150, at the end of this thesis. In the appendix Figure 19 will be accompanied by the full table to explain on what literature the relations are based on.

In Figure 3 it is important to understand the difference of adoption and diffusion. Adoption is the act of adopting a technology by one organization or individual (i.e. the scope is smaller). While on the other hand, diffusion is a measure of omnipresence of a technology in the market as a whole (i.e. the scope is bigger).
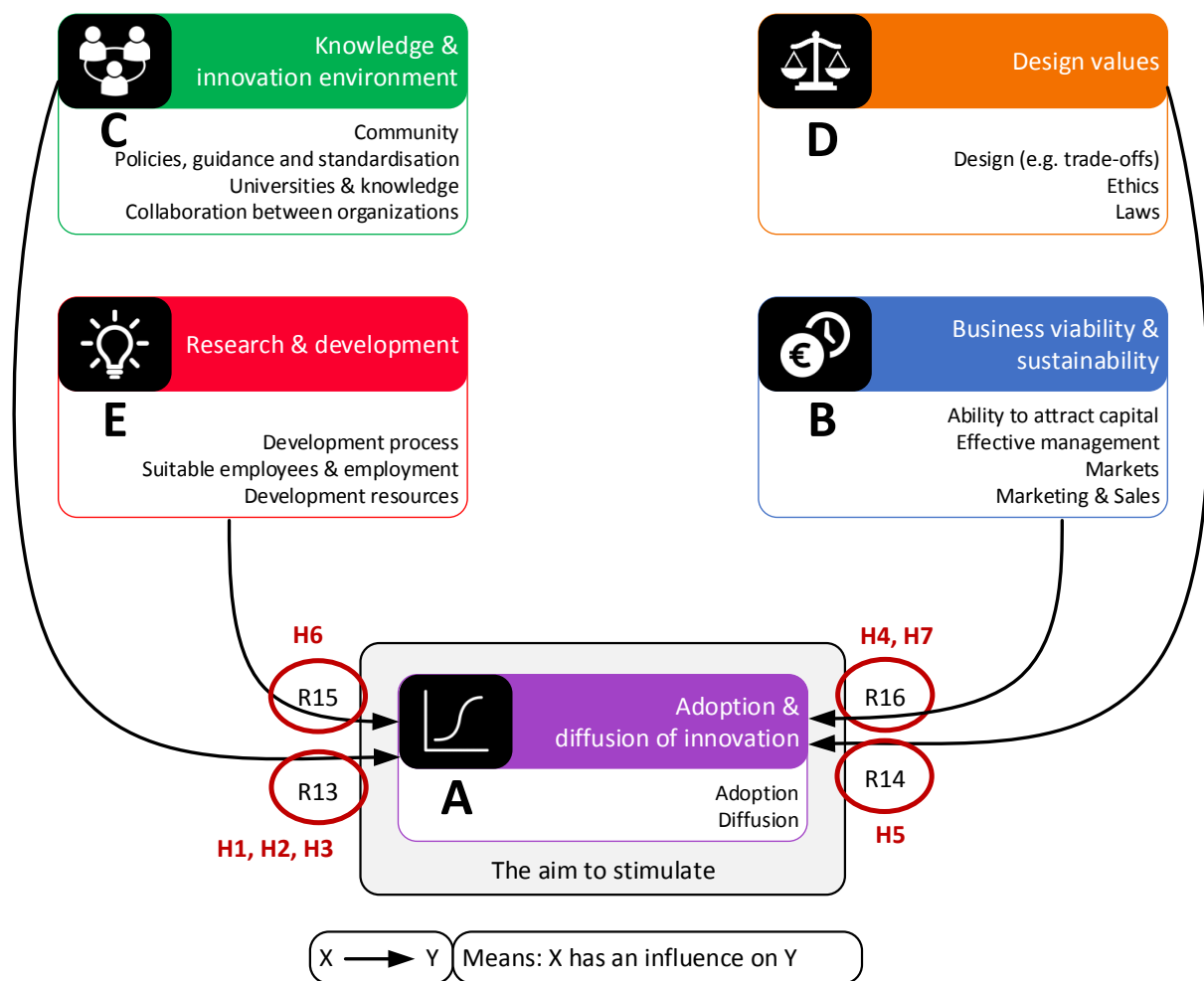
Figure 3 Categories of factors that influence (i.e. drivers and barriers) PET innovation and development (Icons source: Freepik, 2013). A to E means a 'Construct', the R prefix means 'Relation' between constructs.

The conceptual framework examples are established by using academic sources (e.g. papers and books), reports (e.g. ENISA) and interviews with Privacy-Enhancing Technology producers. For example, the six recommendations made by ENISA (D' Acquisto et al., 2015, pp. 5–7) are a fundamental part of creating the model. These recommendations emphasize the relations stated in the conceptual model. See Table 1.

Table 1 Descriptions of relations and their influences of the conceptual model. See schematic representation of conceptual model in Figure 3.

	Factors influencing ADI [a]	Examples/ Notes	Effects on ADI	Source
R13	Strong influence of C on A	• (H1) An environment that creates PET awareness, uses and adopts PETs leads to diffusion throughout technology regimes and eventually the technology landscape	++	(Geels, 2002), (D' Acquisto et al., 2015, p. 6,51)
		• (H2) Incentive mechanisms promote adoption and diffusion	++	(Domingo-Ferrer et al., 2014, p. 50)
			++	(Domingo-Ferrer et al., 2014, pp. 52–53)
		• Infrastructural support allows for lower cost of deploying PETs for all users and operators; which could lead to higher ADI	++	(Domingo-Ferrer et al., 2014, p. 54)
		• Standardisation leads to interoperability and thus usefulness and thus could lead to higher ADI	++	(Domingo-Ferrer et al., 2014, p. 51)
		• Multidisciplinary research in communities lead to more effective PETs and thus could lead to higher ADI		
		• (H3) Data protection authorities, legislative and standardisation guidance	++	(Domingo-Ferrer et al., 2014, p. iii)
R14	Strong influence of D on A	• (H5) Standardisation leads to interoperability, interoperability leads to adoption	++	(Domingo-Ferrer et al., 2014, p. 54)
		• When PETs respect privacy as envisioned by the user, in respect of reliability and usability, awareness and thus could increase ADI	++	(D' Acquisto et al., 2015, p. 51)
R15	Strong influence of E on A	• Automated policy enforcement, that forces other parties to honour a privacy policy creates trust and could increase ADI	++	(D' Acquisto et al., 2015, p. 6)
		• When R&D is done transparently and users can check the code (e.g. open source) trust in a PET increases and thus its adoption and diffusion	++	(D' Acquisto et al., 2015, p. 6,13)
		• PET novelty and complementarities creates value for customers	++	(Amit & Zott, 2001)
		• (H6) Agile, dynamic capabilities allow to respond to fast-changing PET markets and thus captures user demand for features and bug fixes faster	++	(Schilling, 2012, p. 120)
R16	Strong influence of B on A	• (H4) (H7) When a company is trusted due to good management and financial performance, faster idea-to-market is possible with fewer mistakes and could increase adoption	++	(Schilling, 2012, p. 242), (Cooper, 1990a, p. 44)

a. ADI = Adoption and Diffusion of Innovation

4 Methodology

A research strategy is the coherent body of decisions concerning the way in which the research is carried out. Moreover relevant material is gathered and the material is processed into valid answers to the research questions (Verschuren & Doorewaard, 2010, p. 155).

The phases that are spoken of in this chapter correspond with the phases mentioned in sub chapter 2.3 with a schematic representation shown in Figure 1 located in sub chapter 2.4 .

4.1 Research strategy

Taking the set of key decisions, six major strategies can be formed, including (Verschuren & Doorewaard, 2010, pp. 158–160) (Maier, 2016):

1. *Survey*: broad research to find e.g. problems via interviews and questionnaires.
2. *Experiment***:** tests under different conditions in a controlled environment.
3. *Case study*: researching methods and practises that are applied in practise in great detail. Motivations, considerations and reasons for having certain motivations can be researched in detail.
4. *Grounded theory approach*: focusses on developing a theory. Moreover the development of a line of thought and what factors stimulate an orientation are under research.
5. *Desk research*: mainly behind a desk searching in archives and/or in the library. The research builds upon already gathered by others and existing literature.
6. *Design research*: entails employing user experience designers. Design research outputs serve as its inputs. The research delivers how-to knowledge.

As anticipated in sub chapter 2.3 the combination of breadth, qualitative and empirical research is favoured to research methods and practises that are applied in practise. Desk research has been utilised for the first two phases of the research to construct a conceptual model. In contrast, to be able to present generalizable findings and find drivers and barriers to PET adoption & diffusion, and draw generalizable conclusions, survey research is favoured that uses the output of the desk research. It must be noted that the conceptual model presented in section 3.2.4 is a novel creation distilled from PET literature, technology management literature and interviews. The nature of this research required an in-depth assessment and understanding of Privacy-Enhancing Technologies in relation to adoption & diffusion. The strength of building own theory from interviews is the likelihood of generating novel theory which often emerges from juxtaposition of contradicting or paradoxical evidence between multiple interview (Eisenhardt, 1989, p. 546). The strength of this research is that a multitude of interviews is used from individuals with diverse backgrounds in PET innovation.

As stated in section 2.1.2 , the amount of available research on Privacy-Enhancing Technologies in an innovation context is small. However, privacy is a very current issue, which means that the ten

interviews made available by Dr. H. Asghari should present ample additional insight. Not only will the interviews add to a thorough understanding of PET innovation issues, but also form the basis for the questionnaire.

Privacy and innovation experts will be asked to review the questionnaire. The review analysis will also be contemplated with the thesis super visors because this may lead to complementary insights what may benefit the quality of the questionnaire (Eisenhardt, 1989, p. 538).

The context of the interviews should be taken into consideration to better understand with what connotation certain expressions are made. For example when an interviewee explains perceived barriers and challenges in relation to innovation of PETs within a company the explanation could be viewed on three distinct levels as discussed with Dr.ing. V.E Scholten:

1. Firm level
2. (Business) unit level
3. Team level

The awareness of the context in which an interviewee expressed his concerning are thus important to take into consideration to better understand the specific message that is conveyed. However, when describing the findings in phase (e) and (f) the quality of the findings may benefit from not making the context too board. A focus on one unit of analysis is preferred which could include, for example, private businesses or start-ups in contrast to the entire PET developing landscape.

4.2 Scoping

A research strategy is a set of three key decisions from which a number of other decisions will follow (Verschuren & Doorewaard, 2010, pp. 156–157). The first key decision is a decision between *breadth* and *depth*. When opting for breadth a large scale approach follows which enables for generalizable results. Limitations of breadth is the imposed limits on depth, elaboration, complexity and the sound foundation of the results. When opting for depth, the aim is for a small-scale approach that yields knowledge that is generalizable to a lesser extent (than a breadth approach). Benefits of depth are the achievement of elaboration, complexity and soundness and therefore minimising the risk of uncertainty.

The second key decision is between *quantitative* and *qualitative* presentation of the research. With quantitative presentation the research findings are presented in aggregated manners (i.e. via tables, charts, numbers and calculations). With qualitative presentation the research findings are presented in an interpreting manner and are contemplated.

The third key decision involves the decision between *empirical research* (i.e. doing research by going into the field gathering data) and *desk research* (i.e. using existing literature or gathered data by others).

Concerning the first key decision, as depicted by *phases* in sub chapter 2.2 , there are two approaches combined in the total research strategy. The first strategy used in phase (a) and (b) is desk research in a combination of depth research, which is qualitative and based on empirical research (the interviews). Besides the literature, the interviews (qualitative data) will give enough basis to create a questionnaire. Concerning the second key decision, research strategy: analyse the results in phase (c) and (d) which is a quantitative result. The third research strategy depicted in phase (e) with the result in phase (f) is a combination of breadth, quantitative and empirical research.

The research will have alternating diverging and converging stages (Beckman & Barry, 2007). For example, phase (a) is a diverging phase where we have an explorative mindset by gathering all sorts of material that may support a concept we try to convey. In contrast, phase (b) results in a converging step where we pursue abstract conceptualization, active experimentation (Beckman & Barry, 2007) and focus on, and develop an understanding of, a few selected sources that are deemed important and relevant to convey a condensed focused concept. Divergent thinking (i.e. discovering and defining) is succeeded by convergent thinking (i.e. developing delivering, for example a model) a model. While phase (b) is the convergent phase that delivers the conceptual model of PET adoption & diffusion, it is also the start for another divergent phase. Indeed, using interviews as additional input and using review feedback to create a questionnaire needs divergent thinking to explore possible solutions. In contrast, phase (c) is a convergent phase where we focus on what is important and the focus of what we want to deliver (e.g. what questions are most relevant for the questionnaire, what questions to leave out). This process continues for each phase.

The research also alternates qualitative and quantitative research. Phases (a) and (b) are qualitative in nature. In contrast, phases (c), (d) and the deliverable in phase (e) are quantitative in nature. Finally, the part of phase (e) that contains juxtaposition of current policies and management practises and phase (f) are qualitative in nature again.

4.3 Hypotheses

Based on the conceptual model, a set of 9 empirical hypotheses can be developed.

RESEARCH QUESTION: "What factors are drivers and barriers to the adoption and diffusion of Privacy-Enhancing Technologies in private communication and data storage?"

SUB RESEARCH QUESTION 2: "What factors are the most influential drivers and barriers in the adoption and diffusion of Privacy-Enhancing Technologies (PETs) according to producers of PETs?"

HYPOTHESIS 1: Inter-organizational collaboration is a driver to PET adoption & diffusion.

> **Rationale/ details**: *Increased collaboration should lead to the pooling of resources and synergetic effects which should lead to an increase of ideas, (tacit) knowledge, knowledge spill over and a decrease in resources needed to pursue a goal compared to no collaboration.*

HYPOTHESIS 2: The promotion and support of PET development by policy makers is a driver to adoption & diffusion of PETs.

> **Rationale**: *Especially innovations that enter the market should be protected in a niche to mature further. This has been demonstrated by multiple sources* (Geels, 2002) (J. Roland Ortt, Langley, & Pals, 2013). *While the regime in which a niche is developed can protect the niche, policy makers could stimulate PET development further so the (financial) risks involved will be less a barriers to pursue PET development.*

HYPOTHESIS 3: External guidance by standardization bodies, legislators and/or data protection authorities would be a driver to PET adoption & diffusion.

> **Rationale**: *Developing a PET in isolation would require much more resources than utilizing, for example, existing standards, guidelines and concepts. While creating standards in itself is not a product or service for organizations to monetize on, creating e.g. standards and guidelines of best practises is a task that standardization bodies, legislators and data protection authorities are able to fill to benefit PET development and thus society as a whole.*

HYPOTHESIS 4: The most important funding option to smaller organizations (i.e. up to 10 employees) are donations.

> **Rationale**: *The availability of funds for PET development is often problematic show the interviews. With the rise of donation websites this could be the dominant mode of acquiring funds.*

HYPOTHESIS 5: Interoperability between PETs will drive PET adoption and diffusion.

Rationale: *Interoperability of technology could yield the availability of funds for PET development is often problematic show the interviews. With the rise of donation websites this could be the dominant mode of acquiring funds in smaller organizations.*

HYPOTHESIS 6: Agility in an organization is a driver for PET adoption & diffusion.

Rationale: *Agility in an organization means that the development roadmap is often reprioritized based on user input. Also, fixes to bugs or problems with software should be resolved fairly swiftly because of the sprint duration which is typically weeks. When users of PETs see that their concerns are handled shortly after they contacted support their satisfaction of the PET product/service should rise and this the adoption & diffusion of the PET.*

HYPOTHESIS 7: An organization with marketing skills, sales skills and/or a good absorptive capacity should drive adoption & diffusion of PETs.

Rationale: *When an organization is able to absorb external knowledge (Newell, Scarbrough, & Swan, 2009, p. 83) than the ability of that organization to identify, assimilate, transform and apply this external knowledge might lead to a better understanding of the PET under development and thus the ability to develop a PET that better fits the market's need. This in turn should lead to an increase in adoption & diffusion.*

5 Data preparation / Survey setup

This chapter described the data preparation and survey setup. The sub chapters are as follows: first, respondent selection describes the selected actors that are eligible to respond. Second, the sampling procedure is clarified. Third, the measurement procedure is defined. Fourth, the data collection method shows how the data will be collected from the respondents. Fifth, the questionnaire questions are displayed and justified. Sixth, the measuring instruments are presented. Seventh, the limitations of the data preparation are disclosed.

5.1 Respondent selection

The list of considered respondents is primarily based on the interviews. The list was then complemented with respondents that were found in the ENISA reports (Domingo-Ferrer et al., 2014) (D' Acquisto et al., 2015) (Hansen et al., 2015), the literature discussed so far in this thesis, and discussions with experts.

This sub chapter is concerned with who to target for the questionnaire to yield the results that portray reality the best.

The list of considered questionnaire recipients

1. Universities and scholars (TUD, Princeton)
2. Governments using open source
3. Dutch governmental subsidy agencies (RVO)
4. EU governmental subsidy agencies (INTERREG)
5. SME's (up to 250 employees[2]) and corporations, including Cyber Security technology firms
6. Start-ups (Yes Delft, incubators Europe)
7. Non-profit organizations
8. PET open source projects
9. Consultants involved with PETs
10. Standardization bodies (IETF)
11. Cloud service suppliers
12. Granting agencies/ funding platforms
13. Open Technology Fund (OTF)
14. Crowd funding platforms
15. Big donors
16. Company sponsors
17. Volunteers
18. Lead users
19. Hackers
20. Private funders

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[2] http://ec.europa.eu/growth/smes/business-friendly-environment/sme-definition_en

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The considerations, when selecting the best subset of respondents, were primarily based on the resources, relations and the repetitive nature of relations. Based on these characteristics three types of power can be distinguished (Bruijn & Heuvelhof, 2008, pp. 37–38):

1. **Production power**, an actor that can make a positive contribution towards realizing PETs
2. **Blocking power**, an actor that can only halt progress on PETs
3. **Diffuse power position**, an actor with an unclear power position

For this research the interest is primarily in actors with production power. The reason for this is that such actors have the resources and connections to (tacit) knowledge to produce PETs and are most familiar with the drivers and barriers from a practical, hands-on perspective. Moreover, actors with production power are continuously involved with PET development and research in contrast to actors that are sporadically involved with development and research to PETs. The knowledge, experience, beliefs and attitudes of actors with production power is valued the most because we can learn from them towards higher adoption and diffusion of Privacy-Enhancing Technologies.

Other types of actors will not be selected because they are part-time involved (e.g. granting agencies grant many non-PET projects). Many users are part-time involved and do not have a stake in a PET business, such as volunteers, lead users and hackers. However, it is true that such users, or customers, of PETs can play a critical role in value creation (Amit & Zott, 2001), their focus is mainly on the technological side of PET development and research, while a broader perspective of PET adoption and diffusion is of interest for this research. Also governments are not included because they are considered incumbent, bureaucratic, trend-following (instead of trend-setting) organizations.

The expertise and (tacit) knowledge most relevant to this research can be found with the actors selected in the next sub chapter.

5.2 Sampling

Sampling is the process of selecting the right and sufficient subset of elements (i.e. a sample; a subset of all PET producing organizations) from the population (i.e. all PET producing organizations) which make it possible to study the sample and make generalizable claims about the population elements (Sekaran & Bougie, 2013, p. 244). The sampling process is divided in five steps, each described in its own section below.

5.2.1   Define the population

The size of the population of Privacy-Enhancing Technology (PET) producers is unknown. The unit of analysis (i.e. sampling unit) is effectively any organization (i.e. element) from the PET producing organizations (i.e. population).

Initially a wide range of actors was considered involved with PET development and deployment as is shown in Table 2. However, the result of the research would not be generalizable if we included all actors that are both involved and interested in PET development. Therefore the size of the sampling unit has been decreased using three requirements.

First, the group of actors with production power (Bruijn & Heuvelhof, 2008, pp. 37–38) were chosen that are directly responsible for the production of PETs. In contrast, actors that are indirectly involved with PET production (either enabling PET development or blocking development) or actors that have diffuse power (i.e. of which the power position is unclear) are considered out of scope.

Second, only technologies that are enhancing privacy are included. An excellent example for discussion is category 6 Cloud service suppliers (see Table 2) with examples Amazon and Nextcloud. Cloud storage necessitates security and privacy considerations because private data is stored. Therefore cloud solutions are potentially an interesting category to this research. However, distinct solutions are offered and for this research there is on interest only in the privacy-enhancing kind. For example, Nextcloud is a self-hosted solution that focuses on security and privacy in order to give full control to its users over their private data. Moreover, users have the possibility to scrutinize the source code to assert privacy concerns. The most compelling reason to include a cloud service such as Nextcloud in the unit of analysis is their privacy by design approach. In contrast, Amazon Web Services (AWS) is an off-site, proprietary, closed-source cloud solution that ostensibly leaks data to intelligence agencies such as the NSA (Weber, 2014).

Third, organizations must be easy to contact (i.e. convenience sampling). This seems especially false for large corporations. As a matter of preliminary effort IBM and Symantec have been contacted which were both difficult to get a hold on the right person or obtain contact information. For example, IBM is developing a blockchain product which would fit the category of a Privacy-Enhancing Technology. However, after service employees forwarded calls to four different support phone numbers, the phone number that was initially used from the website was given. In effect, we were back where we started. Another example is Symantec, replying six times to a support ticket resulted in nothing. The support staff had asked numerous times what our question was about and that we needed a valid license in order to get support. For this thesis, the effort needed to acquire the needed responses from large corporations were deemed not efficient. Moreover, focussing on smaller organizations could yield results that are better generalizable.

In short, Table 2 categories 1 to 4 are PET producers that belong to the unit of analysis (highlighted in blue). Category 6 is of potential interest (highlighted in green), which deserves additional scrutiny whether the service truly is privacy-enhancing or not.

Table 2 Actors involved and/or interested with PET development (blue = selected; green = conditional selection)

	Category	Examples	Function
1.	Start-ups	Yes Delft, incubators in Europe	Production
2.	Small and Medium-Enterprises	Cyber Security Technology firms	Production
3.	Non-profit, foundations	Mozilla	Production
4.	Open-source projects	Community, volunteers	Production
5.	Corporations	Symantec, IBM	Production
6.	Cloud service suppliers	Amazon AWS, Nextcloud [a]	Production/ Integrators
7.	Universities & scholars	TU Delft, Princeton	Research
8.	Subsidy, government funding	Open Technology Fund (OTF) Dutch governmental subsidy agencies (RVO) European Regional Development Fund (ERDF)	Funding
9.	Crowd funding platforms	Kickstarter, Patreon	Funding
10.	Donors, investors	People that donate, angels	Funding
11.	Company sponsors	Companies help incubate (e.g. CyberGhost)	Funding
12.	Consultants	Deloitte, CGI, NCC Group, EY	Advise
13.	Standardisation bodies	Internet Engineering Task Force (IETF)	Standards
14.	Private organizations	Businesses using PETs	Users
15.	Public organizations	Government, Ministry PET users	Users
16.	Consumers	Home users, personal PET use	Users
17.	Lead users and hackers	People tinkering with bleeding edge PETs	Users

a. Please note that Amazon and Nextcloud starkly contrast in privacy-enhancing qualities. Nextcloud is a self-hosted PET, Amazon is not.

In order to communicate the sampling unit efficiently to respondents in the questionnaire the sampling unit is condensed to three categories of respondents:

1. Companies developing PETs (start-ups, SME's, corporations)
2. Public and non-profit organizations developing PETs
3. Open source PET projects

5.2.2 Sample frame

The sampling frame represents all the elements in the population. The sample itself is drawn from the population (Sekaran & Bougie, 2013, p. 245).

The sample will be extracted from the following sources:

1. Privacy-Enhancing Technology overview websites enlisting PETs
2. Professional privacy associations
3. Interviewed organizations (from qualitative part of research)
4. PETs found while reading about other PETs (i.e. snowball method[3])
5. Respondents forwarding the questionnaire to other interested parties

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[3] Snowball method: new results based on results found thus far (Verschuren & Doorewaard, 2010, p. 201)

Privacy-Enhancing Technologies overview websites to consult are shown in Table 3.

Table 3 Privacy-Enhancing Technologies overview websites

	PET overview websites	**URL**
1.	Privacy Pack	https://pack.resetthenet.org/
2.	Privacytools.io	https://www.privacytools.io/
3.	C2D2 Privacy Projects	https://wiki.c3d2.de/EDN/PrivacyProjects
4.	EPIC Practical Privacy Tools	https://www.epic.org/privacy/tools.html
5.	Peng Zhong's Prism Break	https://prism-break.org/en/all/
7.	European Cyber Security Group	http://cybersecuritygroup.eu/ecsg/members/
8.	Stanford PET list	https://cyberlaw.stanford.edu/wiki/index.php/PET
10.	Dcypher 2017	https://www.dcypher.nl/en/

a. Started: 32 at initial mailing, 21 at reminder. Completed: 22 at initial mailing, 13 at reminder.

b. added in reminder round.

Professional privacy associations that have been contacted are shown in Table 4.

Table 4 Professional privacy associations

	Professional privacy associations	**URL**
11.	PET Symposium	https://petsymposium.org/
12.	IAPP, International Association of Privacy Professionals	https://iapp.org/
13.	IAPP Australia/New Zealand	http://www.iappanz.org/
14.	ADPO, The Association of Data Protection Officers (Ireland)	https://www.dpo.ie/
15.	AFCDP, French Association of Data Protection Correspondents	http://www.afcdp.net/
16.	APEP, Associación Profesional Española de Privacidad (Spain)	http://www.apep.es/
17.	DSCI, Data Security Council of India	http://www.dsci.in/index.php
18.	GDD, German Association for Data Protection and Data Security	http://www.gdd.de/
19.	IMM, The Institute of Information Management (IIM) Africa	http://www.iim-africa.org/
20.	CPO, Korea CPO Forum	http://www.cpoforum.or.kr/
21.	NGFG, Nederlands Genootschap van Functionarissen voor de Gegevensbescherming (Netherlands)	http://www.ngfg.nl/
22.	UK Data Protection Forum	http://www.dpforum.org.uk/
23.	PvIB, Platform voor InformatieBeveiliging (Netherlands)	https://www.pvib.nl/en

Completed questionnaires may contain n/a (i.e. not available or not applicable) responses yielding fewer fully answered questionnaires in total.

5.2.3   Survey setup

Preparation and data collection for the survey consists of five steps:

First, a draft questionnaire will be designed based on the input from the desk research, literature and thesis advisor discussions.

Second, the questionnaire needs to be checked on terminology and validity. Checking the questionnaire by review allows for removing bias from questions and rectifying before the questionnaire is being mass sent. One or two thesis advisors and/or other people with an academic background that have experience with questionnaires test the questionnaire.

Third, the feedback is used to correct the questionnaire by deleting items, adding items and changing items.

Fourth, Phil Zimmerman, and expert in the field of privacy is asked to review the questionnaire and his feedback will be analysed and incorporated in the questionnaire.

Fifth and finally, the survey will be sent to a group of recipients that comply with the sample frame. The survey will be spread via a link on-line.

Choosing for an on-line questionnaire has advantages. The response time of e-mail sent questionnaire opposed to regular mail sent questionnaires tends to be lower (i.e. days instead of weeks), while the response rate of questionnaires sent by regular mail are sometimes higher. Furthermore on-line surveys require minimal financial resources even when the scale of the survey increases. Moreover e-mail surveys provide more detailed and comprehensive information than regular mail surveys. The data quality of e-mail surveys is higher than that of regular mail surveys (Ilieva, Baron, & Healey, 2001, pp. 10–12). The impact of pre-notification before sending a survey on the speed of the responses bare a positive relationship (Ilieva et al., 2001, p. 10). It is concluded that an e-mail survey is sent to the questionnaire recipients and prior to sending the questionnaire a pre-notification is sent.

Control questions and both dependent and independent questions will be placed in an appropriate category. The most important category will be placed first (i.e. adoption & diffusion). In case a respondent stops the questionnaire at least the first category has been received and stored.

Generalizability should hold towards PET developing and innovating companies. Based on the findings in the interviews the total affected population can be estimated. This estimation can be used to establish what the sample size needs to be. However, in general a sample size of around 400 is preferred due covering a large populations of up to 300 million (confidence 95% and error margin 5%). A sample size of up to 700 would allow the research to have a higher confidence (namely 99% and error margin of 5%). The used confidence and error margin will depend on the number of respondents. Because it is allowed to forward the questionnaire a higher response rate may be acquired due to the snowball effect.

5.3 Measurement considerations

This sub chapter describes what issues were taken into consideration when creating the questionnaire.

In the early stage of creating the questionnaire the difficulty of doing a structured questionnaire became clear. On the one hand structured questions would force respondents to answer in a certain manner and hence information will be lost. On the other hand, the processing of open questions is very time consuming and the findings are difficult to generalize. Nevertheless, the amount of information conveyed in open questions contains much more depth and context; responses are thus richer. The ideal situation would be to receive structured answers for statistical analysis and to still be able to capture information of heavy contributors that contribute much contextual and in-depth information. To resolve this problem the concept of Wiki Survey (Salganik & Levy, 2015) (Salganik, 2017) is introduced into the questionnaire. The original Wiki Survey approach allows respondents to give a structured answer or create an answer of their own which in turn can be responded to by other respondents. However, the approach used in this thesis allows the respondent to answer in an optional text field at the end of each category. This approach should allow to capture the context rich information that heavy contributors are eager to give away (see the arrow pointing to the additional context rich information captured in Figure 4). Moreover, this rich context not only helps us to understand the context of the responses in each category but may also give insights in overlooked issues in the questionnaire development and can be used as a pointer for future research.
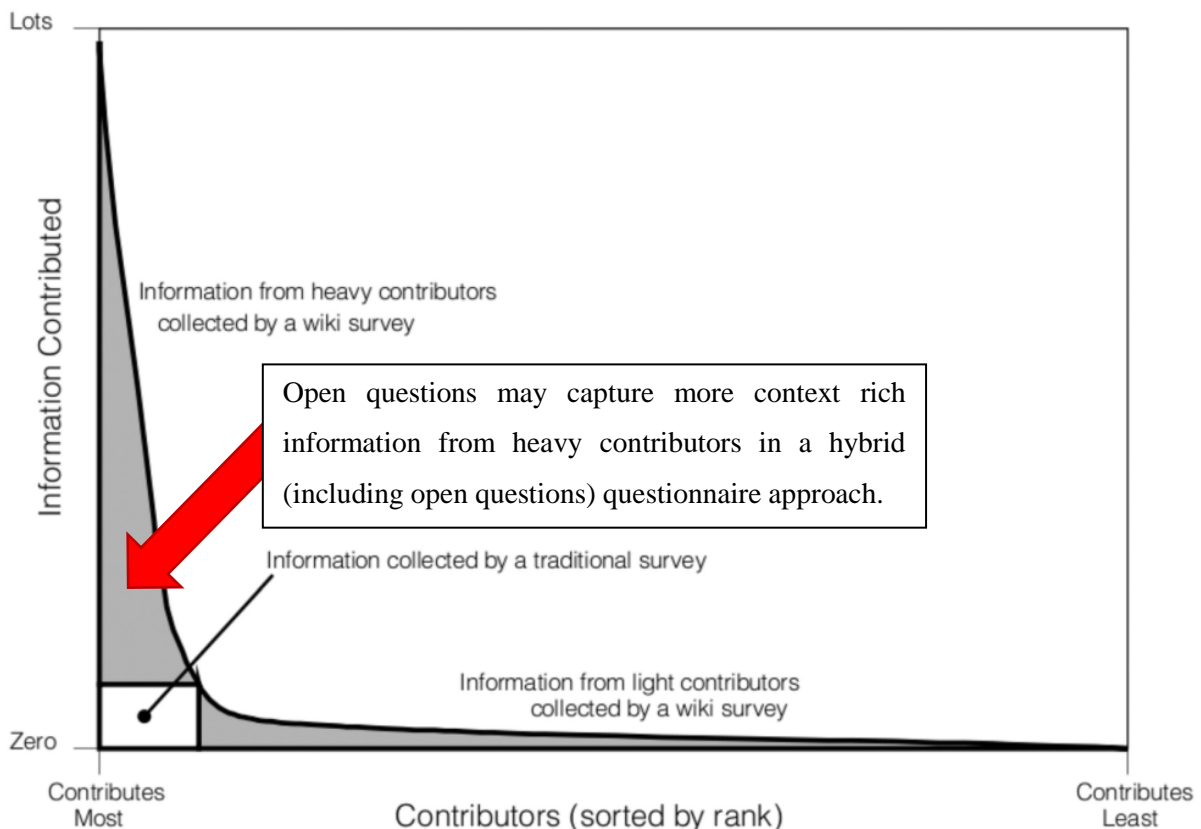
Figure 4 A semi-quantifiable approach using the Wiki Survey approach

Another important issue is recoding. Recoding is an important issue to take into consideration because it may cause distorted or even incorrect results during statistical analysis. Field states that reverse-

phrased questions in a questionnaire are important for reducing response bias because participants need to pay extra attention to the questions (Field, 2013, p. 710). However, reverse-phrasing part of the questions introduces the risk of errors made by respondents. In addition, reverse-phrasing introduces an increased risk for errors made by the researcher because recoding is an extra step introduced into the analysis. For our questionnaire, questions are stated positively and always use the same scale (e.g. strongly disagree on the left die to strongly agree on the right side). While questions like "Privacy design is an afterthought" might need recoding to reverse the scale, there is no practical reason to do so. In particular, there is no structural redundancy of questions that may need scale to align. Also, validated negative questions and statements (e.g. containing 'not') will be rephrased in a positive form (e.g. removing the 'not') because negatively postured statements are often more confusing to respondents.

Another point of interest is the lack of usage of the term compatibility in the questionnaire. Especially some validated questions from the literature (Moore & Benbasat, 1991) include compatibility as a measure of adoption & diffusion. With IT systems the term compatibility is deemed confusing because IT systems do not necessarily need to be compatible as long as they are able to communicate with each other. Therefore the term interoperability is chosen to be more specific about the type of compatibility. Also ENISA refers to interoperability as an important part of collaborative privacy engineering (Domingo-Ferrer et al., 2014, p. 54).

An important question presented by Dr. Phil Zimmermann during the review was that the *cognitive load* (or *cognitive burden*) with users should be low. A cognitive load is the experienced difficulty of the task at hand (Ariely, 2000). An increase in cognitive burden means a decrease in the performance on a comprehension task. This notion is supported by the dimension *ease of use* by Moore's adoption & diffusion model (Moore & Benbasat, 1991). In addition, the cognitive load issue also applies to the questionnaire itself. The questions asked in the questionnaire should be easy to understand and also have a conversational tone to engage the respondent.

The validity of questions have been taken into account by using validated questionnaire questions from the literature where possible, for example Moore's validated adoption & diffusion scale questions. For PET specific questions expert feedback was analysed to see how they responded to certain questions and what issues were noticed that needed to be resolved.

As a rule of thumb, no more than 40 questions should be asked to keep the dropout rate low. However, the expert feedback resulted in additional questions. Also, the redundancy introduced by Moore's adoption & diffusion questions introduced additional questions. In the end, about 60 question were included in the questionnaire. However, also many questions were not included in the questionnaire because they were considered out of scope. Especially questions that do not belong to one of the categories from the conceptual model were considered out of scope.

The order of questions have been considered as well. For example, the first category (adoption & diffusion) starts with the question "Please describe the main Privacy-enhancing product/service of your organization (e.g. VPN, secure email, self-hosted cloud storage, ad blockers, etc) or the PET that you have worked on in the past." This question is intended to get the respondent sharp on the context in which he/she will answer the rest of the questions. Furthermore, the order of categories has also been taken into account. The *adoption & diffusion* category is asked first and *business viability & sustainability* second in case a respondent may choose to dropout. When a respondent drops out, we at least have captured the most important category: adoption & diffusion.

Concerning the Likert scale, the difference between a 4-point Likert scale (i.e. no neutral mid-point) and a 5-point Likert scale (i.e. having a neutral mid-point) can have a considerable negative effect on the results (Garland, 1991). The reason for this is that respondents would be forced to choose a side on a 4-point Likert scale. We choose to use a 7-point Likert scale both because of the increased reliability and the additional granularity of having two additional options.

5.4 Data collection method

Consideration and limitations of Survalyzer Collector.

Questionnaire software like Qualtrics and CampusLabs have great features but no explicit policies regarding the ownership of data[4]. On the other hand, Survalyzer Collector explicitly states that the ownership of all data collected by Survalyzer solely lies with the customer[5]. Because of this core feature, for this thesis Survalyzer is the appropriate choice. However, Survalyzer 2013.Q3.SP1 does have the disadvantage of lower administration usability because the browser compatibility is limited to Internet Explorer (at a time when Edge replaced Internet Explorer) and FireFox (at a time that Google Chrome has the majority market share in most countries). Moreover, mobile browser compatibility for respondents is low in Collector. Lastly, the faculty of Technology, Policy and Management of the TU Delft only offers the Survalyzer option. It would be time prohibitive to use an alternative, while a self-hosted, privacy respecting and sensible licensed (i.e. data ownership) is available.

The choice has been made to use Survalyzer Collector. After testing a published survey, it worked also on Safari (iPad) and Chrome (Windows PC).

5.5 Juxtaposing literature and interviews

The written interviews used totalled over 80,000 words. Many concepts discussed could also be found in the literature. However, the context could make some issues more salient. For example, funding for

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[4] https://www.umresearch.umd.edu/RCO/New/OnlineSurveyResearchGuidance.pdf
[5] http://www.survalyzer.com/product-security/

innovation is always important, however, finding funding for privacy which is often not seen as a product or service itself can be more difficult. Moreover, the would be more risk involved in PET development than in regular ICT development which results in less investors willing to invest in PET innovation.

Especially valuable were the issue sin the interviews that added to the literature. For example, funding is important. But it is difficult to find in the literature what types of funding are considered important to PET development. In the interviews many options were discussed. This allowed us to create a list of options in order to make the questionnaire less of a burden to the respondent on the one hand, and to make analysis on the responses easier (because the responses are standardized). For example, after discussing funding options like Patreon, Flattr and OTF we were able to find generalized terms for these types of funding and place these options in the questionnaire.

5.6 Questionnaire questions

The origin of questionnaire questions lie with the interviews taken by Dr. H. Asghari. There are in total 10 interviews used in this research. Six interviews were already transcribed and three interviews were already summarized by Dr. H. Asghari. One interview has been transcribed in full during this thesis work. The interviews have been used to establish a preliminary list of questions by identifying concepts, events, topical markers and themes. The importance has been underlined using privacy and management literature. To operationalize adoption & diffusion the literature by Moore has been used to combine privacy engineering with validated adoption & diffusion scales (Moore & Benbasat, 1991). The eight Moore scale question of adoption & diffusion will be part of the questionnaire in an effort to strengthen the validity of the research. The full questionnaire (using the original question codes, i.e. before moving some questions to new categories) can be found in "Appendix C: The questionnaire".

There will be made use of references in explaining the rationale behind questions. The abbreviated references point to the full references in Table 5.

Table 5 Abbreviated references used to explain the rational behind questions.

	Abbreviated reference	Full reference
1.	Soetanto 2009	(Soetanto, 2009, pp. 126–129)
2.	ENISA 2014	(Domingo-Ferrer et al., 2014)
3.	ENISA 2015	(D' Acquisto et al., 2015)
4.	Salganik 2015	(Salganik, 2017)
		(Salganik & Levy, 2015)
5.	Moore 1991	(Moore & Benbasat, 1991)
6.	Lund 2001	(Lund, 2001)
7.	Interviews	Questions distilled from interview transcripts/ recordings
8.	Asghari	Dr. Hadi Asghari (TU Delft, Privacy Economics)
9.	Scholten	Dr.ing. Victor Scholten (TU Delft, Entrepreneurship)
10.	Ortt	Dr. Roland Ortt suggestion (TU Delft, Innovation)

10.	Zimmermann	Dr. Phil Zimmermann suggestion (TU Delft/ MIT, Computer Science)
11.	Mahieu	PhD. candidate René Mahieu suggestion (TU Delft, Cyber Security)
12.	Michota	PhD. candidate Alexandra Michota (ENISA and University of Piraeus, Network Security & Privacy)

The type of question is denoted using one of the abbreviated codes in Table 6.

Table 6 The abbreviated codes used to emphasize the type of question in the questionnaire.

	Abbreviated type	**Type of question**
1.	L7	7-point Likert scale question
2.	L5	5-point Likert scale question
3.	O	Open question
4.	M	Multiple choice question
5.	MO	Multiple choice question with open 'Other' possibility
6.	V	A validated question from the literature
7.	E	A question deemed relevant by an expert or the literature
8.	C	May be used as a control question

The questionnaire questions introduced based on Moore & Benbasat (1991) will be highlighted by the reference [Moore 1991] and a grey background.

	Adoption & diffusion of innovation	Construct questions

	Question/statement, rationale and [source]	Type
1.	[FA01M] Please describe the main Privacy-enhancing product/service of your organization (e.g. VPN, secure email, self-hosted cloud storage, ad blockers, etc) or the PET that you have worked on in the past. **Rationale**: Setting the mind of the responder to a specific PET product/service in order to answer the rest of the questionnaire questions accordingly. Positioning of question moved to the first place for this reason [Asghari]	O, C
2.	[A02M_A] The Privacy-Enhancing Technology (PET) product/service we produce is very visible to the market. **Rationale**: One of the 8 scales to study adoption and diffusion [Moore 1991]. And also an ENISA issue [ENISA 2015, p51]	L7,V
3.	[A02M_B] The demand for our PET product/service by private consumers is high. **Rationale**: A validated question to test consumer demand [Soetanto 2009]	L7,V
4.	[A02M_C] The demand for our PET product/service by private businesses is high. **Rationale**: A validated question to test business demand [Soetanto 2009]	L7,V
5.	[A02M_D] The demand for our PET product/service by public organizations is high. **Rationale**: Besides consumers and businesses there is also a market for public organizations [Ortt]	L7,V
6.	[A02M_E] Users would have no difficulty telling others about the results of using our PET product/service. **Rationale**: One of the 8 scales to study adoption and diffusion [Moore 1991]	L7,V
7.	[A02M_F] We have noticed a growth in use or sales of the PET product/service in the last year. **Rationale**: Besides uptake in mental grasp, uptake may be interpreted as 'increase in sales or use' which is an extra measure to measure a momentum instead of a single point in time [Mahieu] [Scholten]	L7,E

8. [A08O] Which other important factors stimulate adoption and diffusion of PETs according to you? O
   Please also indicated if your organization supports them well.
   Rationale: An open question, like Wiki Surveys, an opportunity to speak freely [Salganik 2015]

	Business viability & sustainability	Construct questions

	Question/statement, rationale and [source]	Type
9.	[B01M_A] My organization has marketing knowledge. **Rationale**: testing the ability to market the PET product/service favourably [Soetanto 2009]	L7,V
10.	[B01M_B] My organization has sales skills. **Rationale**: Ability to sell the PET [Soetanto 2009]	L7,V
11.	[B01M_C] My organization has managerial skills to handle tasks effectively. **Rationale**: Ability to solve obstacles faced by organizations [Soetanto 2009]	L7,V
12.	[B01M_D] My organization has forecasting capabilities about the future market. **Rationale**: Having market related knowledge [Soetanto 2009]	L7,V
13.	[B01M_E] The business model (i.e. how you earn revenue) of our PET product/service is profitable. **Rationale**: The ability to align activities to make a profit. In an earlier version we asked whether the BM was 'stable'. Continuously losing money is also considered 'stable', so we could change it to 'good' or 'profitable'. [Zimmermann] Note: non-profits could answer this question neutrally or even negatively because of the nature of a non-profit.	L7,E
14.	[B01M_F] My organization has easy access to investment capital, including R&D investment. **Rationale**: Ability to acquire financial resources which is a requirement for sustained activities to be able to cover expenses and invest in development [ENISA 2014] [Soetanto 2009]	L7,V
15.	[B01M_G] Our PET product/service needs monetary public support to develop and thrive. **Rationale**: Dependence on public monetary support to remain solvent [ENISA 2014, p. iv]	L7,E
16.	[B01M_H] Getting funding is a very bureaucratic process (e.g. procedures to get grants/subsidies). **Rationale**: The ability of an organization to process administrative tasks necessary to attain public monetary support [ENISA 2014, p. iv]	L7,E
17.	[B01M_I] Finding risk-taking funders for our PET product/service is easy. **Rationale**: The ability of a firm to convince investors to support their cause [Zimmermann]	L7,E
18.	[B01M_J] Competition in our market is intense. **Rationale**: The context in which the answers in this category should be placed.	L7
19.	[B10M] What is the most important funding option that your organization utilizes for PET projects, excluding revenues from sales & subscriptions? **Rationale**: A way to find out what the most important type of funding is under the respondents.	MO,E
20.	[BD19M_A] Under what license is your PET product/service created? **Rationale**: How to market the PET, possibly in relation to the business model [Asghari]	L7,E
21.	[BE01M_F] My organization has experienced growth in uptake (i.e. understanding, mental grasp) of the PET product/service in the last year. **Rationale**: See, whether there is a trend in absorptive capability [Asghari]	L7,E
22.	[B15O] Which other important factors do you know for the business viability & sustainability of PET development/deployment? Please indicate how your organization capatilizes on these factors? **Rationale**: An open question, like Wiki Surveys, an opportunity to speak freely [Salganik 2015]	O
23.	[FB11M] Total number of employees/ staff of organization; or if you do not form a legal entity, your organization is the total number of people involved with the PET. **Rationale**: A control question for when needed during analysis.	O,C
24.	[FB12M] Annual revenue in the last year (in Euro). Or if you are a non-profit organization, annual budget. **Rationale**: A control question for when needed during analysis.	O,C
25.	[FB13M] Main source of revenue. Or if you are a non-profit organization, main source of budget spending.	MO,C

Rationale: A control question for when needed during analysis.

26. [FB14O] Annual revenue growth (in %) as an average of the last 3 years . Or if you are a non-profit   O
organization, annual budget growth (in %).
Rationale: An open question, like Wiki Surveys, an opportunity to speak freely [Salganik 2015]

	Knowledge & innovation environment	Construct questions

Question/statement, rationale and [source]	**Type**
27. [C01M_A] My organization has easy access to technical knowledge needed for the development of PETs (e.g from a university or research centre). **Rationale**: For understanding whether collaboration comes from universities and technology centers. [Soetanto 2009]	L7,V
28. [C01M_B] My organization is part of an environment where it is easy to talk with anyone we need to, regardless of rank or position. **Rationale**: To understand how formal (e.g. powerdistance (Hofstede et al., 2010)) the environment is as a driving or impeding factor [Soetanto 2009]	L7,V
29. [C01M_C] My organization cooperates with other PET producing firms. **Rationale**: A general question concerning cooperation between organizations in the environment (i.e. outside the own organization)	L7
30. [C01M_D] My organization cooperates with policy makers that support the development of PETs. [ENISA 2014, p.iv] **Rationale**: Measure the cooperation with policy makers to support the development of PETs	L7,E
31. [C01M_E] My organization participates in a regional community to promote privacy engineering. **Rationale**: Whether the promotion of PETs occurs between organization (and thus without policy makers).	L7
32. [C13O] Which other important environmental (e.g. market) factors stimulate PETs according to you? Please also state whether they are supported in your organization. **Rationale**: An open question, like Wiki Surveys, an opportunity to speak freely [Salganik 2015]	O
33. [C01M_F] Data protection authorities' guidance plays an important role in our PET design. [ENISA 2014, p.53] **Rationale**: One of the three bodies that can offer guidance in PET development. Is this body important as a form of guidance?	L7,E
34. [C01M_G] Standards (from standardisation bodies) play an important role in our PET design. [ENISA 2014, p.53] **Rationale**: One of the three bodies that can offer guidance in PET development. Is this body important as a form of guidance?	L7,E
35. [C01M_H] The law is an important source of guidance in our PET design. [ENISA 2014, p.53] **Rationale**: One of the three bodies that can offer guidance in PET development. Is this body important as a form of guidance?	L7,E
36. [CD01M_E] Our PET product/service makes good use of existing IT systems (e.g. public key servers, remote servers and clouds). [ENISA 2014, p.52] **Rationale**: A factor considered important by ENISA. However, do organizations make good use of existing IT systems to develop PETs?	L7,E
37. [CD01M_P] My organization uses PETs that are designed by other organizations. **Rationale**: besides the infrastructure, do organizations use PETs that are designed by other organizations (i.e. outsource to the environment)?	L7
38. [FC12M] In which country is your organization mainly based (i.e. workplace)? Or if that has changed over time, in what country did most development and management decisions take place? **Rationale**: A control question for when needed during analysis.	O,C

Design values   Construct questions

01)00 Question/statement, rationale and [source]	Type
39. [D01M_A] Customers are satisfied with our PET product/service. **Rationale**: Satisfaction is highly correlated with ease of use. It is a variable that is a bit out of place but incorporates the perceived ease of use and usability of the PET [Lund 2001]; One of the 8 scales to study adoption and diffusion [Moore 1991]	L7,V
40. [D01M_B] Customers find our PET product/service easy to use. **Rationale**: the perceived ease of use and usability of the PET [Lund 2001]. Also an ENISA issue of usability [ENISA 2015, p51]. One of the 8 scales to study adoption and diffusion [Moore 1991]	L7,V
41. [D01M_C] Users are able to properly try out our PET product/service, before deciding whether to use it. **Rationale**: One of the 8 scales to study adoption and diffusion [Moore 1991]	L7,V
42. [D01M_D] Our PET product/service gives users more control over their personal data processing. **Rationale**: One of the 8 scales to study adoption and diffusion [Moore 1991]	L7,V
43. [D01M_F] We offer open access to the inner-workings of our PET product/service (e.g. open source, database access, public auditing). **Rationale**: A measure of openness about the PET product/service. [ENISA 2015, p.06]	L7,E
44. [D01M_G] Privacy is sometimes an afterthought in our PET product/service design. **Rationale**: Are there non-privacy issues considered important? In other words, is privacy by design adhered to? [ENISA 2015, p.05]	L7
45. [D01M_H] Our PET product/service ensures increased privacy with big data. **Rationale**: [ENISA 2015, p.06]	L7,E
46. [D01M_L] Laws that don't respect privacy incentivizes our organization to create PET products/services. **Rationale**: While the law may guide PET design the reverse may also be possible: that laws that don't respect privacy are an incentive to produce PETs. This question is closer to the design category than to the environment category because this question revolves round a value of the developers. [Zimmermann]	L7, E
47. [D01M_M] Users are required to use our PET product/service by their superior (e.g. a boss) or by law. **Rationale**: One of the 8 scales to study adoption and diffusion [Moore 1991]	L7,V
48. [D01M_N] Our PET product/service has automated privacy policy enforcement. **Rationale**: Whether policies are enforced or requires the user to make decisions (and thus possible errors). [ENISA 2015, p.06]	L7,E
49. [D01M_O] Our PET product/service does decentralised data analytics. **Rationale**: Good privacy sometimes means decentralization. Especially decentralized analytics empowers users. Automating the prevention of unauthorized access between systems. The ability for users to grant and withdraw consent for access to personal data that is part of big data. [ENISA 2015, p.05,48]	L7,E
50. [D01M_Q] PET interoperability with other PETs is important. **Rationale**: Test whether interoperability is important to a PET developer. Interoperability is not always considered important. For example, because of proprietary protocols to make the PET possible. [Zimmermann] One of the 8 scales to study adoption and diffusion [Moore 1991]	L7,E
51. [D01M_R] Our PET product/service has high interoperability with other PETs. **Rationale**: Whether a PET actually has high interoperability with other PETs. One of the 8 scales to study adoption and diffusion [Moore 1991]	L7
52. [DE08M_A] My organization asks itself why it innovates the PET product/service (compared to what and how to innovate). **Rationale**: Focussing on what and how to develop may forego the primary question: "should we develop this PET?" as part of a viability issue (Cooper, 1990a). However, the question is placed in the *value* category because the question is mostly intended to measure whether a PET developer continuously tests whether their values are embedded in the product; whether they	L7

are still faring the course intended (e.g. Privacy by design). Also, The likelihood of innovating new products and services increases when a firm knows when to ask the right what, why, how or who question in the right context (Jensen, Johnson, Lorenz, & Lundvall, 2007).

53.	[D20O] Do you know other important values to consider in the design, development and deployment of PET products/services? Please state whether these key values play a key role in how your organization operates. **Rationale**: An open question, like Wiki Surveys, an opportunity to speak freely [Salganik 2015]	O

 Research & development
Construct questions

	Question/statement, rationale and [source]	Type
54.	[E01M_A] My organization uses an on-line platform to create and share PETs. **Rationale**: This question tries to find out whether an organization does indeed use an on-line collaborative environment in their development process or not. A collaborative platform is considered important. [ENISA 2014, p.54]	L7,E
55.	[E01M_B] We use feedback of our users to update the development roadmap. **Rationale**: A measure of agility of the organization (i.e. organic vs mechanistic organization structure) (Schilling, 2012, p. 212).	L7,E
56.	[E01M_C] Fixing critical errors and bugs is of highest importance to our PET product/service. **Rationale**: A measure of agility of the organization (i.e. organic vs mechanistic organization structure) (Schilling, 2012, p. 212).	L7,E
57.	[E01M_D] My organization defines goals at the start of each project. **Rationale**: A measure of agility of the organization (i.e. organic vs mechanistic organization structure) (Schilling, 2012, p. 212). Better privacy adhering quality could be delivered if goals are set (Cooper, 1990a).	L7,E
58.	[E01M_E] My team is geographically centralized (e.g. working close to each other). **Rationale**: Centralization of the organization vs decentralization (Schilling, 2012, pp. 211–212).	L7,E
59.	[E07M_A] How formalized is your software management process? **Rationale**: A measure of agility of the organization (i.e. organic vs mechanistic organization structure) (Schilling, 2012, p. 212).	L7
60.	[E12O] Which other important factors do you know for the research & development of PETs? Please state if they are well-facilitated in your organization. **Rationale**: An open question, like Wiki Surveys, an opportunity to speak freely [Salganik 2015]	O
61.	[E01M_F2] We can easily find employees with technical skills (e.g. computer science and engineering) that are suitable for our organization. **Rationale**: Finding the right employees for the organization where the employment also has the right offer for the employee. [Soetanto 2009]	L7, V
62.	[E01M_F3] We can easily find employees with non-technical skills (e.g. economics, law, psychology and ethics) that are suitable for our organization. **Rationale**: Finding the right employees for the organization where the employment also has the right offer for the employee. [Soetanto 2009]	L7, V
63.	[E01M_F4] We can easily find employees with multidisciplinary skills (i.e both technical and non-technical skills) that are suitable for our organization. **Rationale**: Finding the right employees for the organization where the employment also has the right offer for the employee. [ENISA 2014,p51] [Soetanto 2009]	L7, V
64.	[EC01M_I] Our organization experiences too strict employment and labour laws (i.e. protecting employees) that have a negative effect on our innovative abilities. **Rationale**: [Zimmermann]	L7
65.	[EC01M_J] We heavily rely on 3rd party technology (e.g. open source). **Rationale**: See whether the development process requires a 3rd party technology in order to be developed (e.g. Tor). [ENISA 2014, p.31]	L7, E
66.	[EC01M_K] We require a component or infrastructure that is not available yet.	L7

Rationale: See whether a critical infrastructure part is missing in order to develop the PET. Derived from EC01M_J.

67. [FE09M] PET producing experience of your organization (in years). O,C
    Rationale: A control question for when needed during analysis. [Soetanto 2009]

68. [FE10M] Amount of staff involved with PET R&D (in %); for small non-profit open-source projects O,C this is most likely '100' (%).
    Rationale: A control question for when needed during analysis. [Soetanto 2009]

69. [FE11M] I and most of my colleagues have completed... (highest degree completed by most O,C people)
    Rationale: A control question for when needed during analysis.

5.7 Questions changing category

A total of eight questions have been moved to other categories while exploring the sample. This move has already been processed in earlier chapter in order to keep the thesis easier to read. However, the questions coding in "Appendix C: The questionnaire" still use the old coding and category placement. The questions that have changed from category and their rationale are shown below.

MOVED TO CATEGORY B

[BD19M_A] Under what license is your PET product/service created?

> **Rationale**:
>
> Decision based on logic. It was deemed more appropriate to see how a licensing issue fits in a business viability context. Indeed, the license depends heavily on the monetization strategy.

[BE01M_F] My organization has experienced growth in uptake (i.e. understanding, mental grasp) of the PET product/service in the last year.

> **Rationale**:
>
> Based on logic and correlation matrix. "Appendix G: Correlation matrix r > 0.45" shows the Spearman's r correlation matrix. A moderate, almost strong, correlation exists with question "[B01M_D] My organization has forecasting capabilities about the future market." The uptake question was probably not interpreted by the respondents in relation to R&D but rather as a market understanding.

MOVED TO CATEGORY C

[CD01M_E] Our PET product/service makes good use of existing IT systems (e.g. public key servers, remote servers and clouds).

> **Rationale**:

Decision based on logic. The question is focused on IT systems in the environment (i.e. collaborative), which makes it a suitable question to be placed in the environment category.

[CD01M_P] My organization uses PETs that are designed by other organizations.

Rationale:

Using PETs designed by others needs a high level of trust in other parties and thus signifies collaboration efforts between organizations.

MOVED TO CATEGORY D

[DE08M_A] My organization asks itself why it innovates the PET product/service (compared to what and how to innovate).

Rationale:

Decision based on logic. Focussing on what and how to develop may forego the primary question: "should we develop this PET in the first place?" as part of a viability issue (Cooper, 1990a). This signifies a *Business viability* issue. However, the question is placed in the *value* category because the question is mostly intended to measure whether a PET developer continuously tests whether their values are embedded in the product; whether they are still faring the course intended (e.g. Privacy by design). Also, The likelihood of innovating new products and services increases when a firm knows when to ask the right what, why, how or who question in the right context (Jensen et al., 2007) this means considering other values to come to a weighted conclusion.

MOVED TO CATEGORY E

[EC01M_I] Our organization experiences too strict employment and labour laws (i.e. protecting employees) that have a negative effect on our innovative abilities.

> **Rationale**:
>
> Decision based on logic. While labour law is an important environmental variable, it may fit better with the employees hired within a firm. If any important relation between finding the right employees and the law arises. Therefore it was deemed more appropriate to more the variable.

[EC01M_J] We heavily rely on 3rd party technology (e.g. open source).

> **Rationale**:
>
> Decision based on logic. Instead of seeing this as an environmental collaborative issue it is rather a dependency in the development process.

[EC01M_K] We require a component or infrastructure that is not available yet.

> **Rationale**:
>
> Decision based on logic. Rather than seeing this issue as part of a collaborative issue it is better seen as requirement for PET development within the development process. The variables in category C *environment* may then be utilised if a need arises to outsource de production of the necessary component.

5.8 Measuring instruments

For statistical analysis, many instruments can be used to understand individual variables and the relation between variables. These instruments have certain properties in the form of advantages and disadvantages. Depending on the advantages and disadvantages the quality of one measuring instrument might be higher than that of the other. The aim of this thesis is to be explicit why certain measuring instruments are used.

5.8.1   Cronbach Alpha

For reliability analysis of the dataset we use Cronbach's alpha (α). Cronbach's alpha can be used for the whole dataset to check the validity (i.e. do we reliably measure what we want to measure; did we ask the right question) of individual items. However, when measuring the Cronbach's alpha of items that belong to the same factor after factor analysis, the Cronbach's alpha should be performed merely on that subset (i.e. subscale) of items (Field, 2013, p. 709). Another point of attention is that the Cronbach's alpha in a subscale is sensitive to reverse questioning thus recoding (i.e. reversing the scale) will be necessary (Field, 2013, p. 710).

5.8.2   Bivariate correlation

The Pearson correlation (r) is one of the most often used statistical estimators. Nevertheless, would it be appropriate to use it in this thesis because of this sole reason? For instance, a Pearson correlation value may be seriously affected by only one outlier; which is bad for robustness of the measure. Besides the Kendall correlation (τ) measure being vastly more robust than Pearson's r and slightly more robust than Spearman's rank (ρ), Kendall's tau is also slightly more efficient than Spearman's r, while Kendall's tau remains efficient when a non-normal distributed sample is processed (e.g. skewness) is more robust (Croux & Dehon, 2010) (Helsel & Hirsch, 1992, pp. 212–220). This makes Kendall's tau a preferable estimator from both robustness and efficiency perspectives. Some papers even discard Pearson's r completely when the assumption of bivariate normality cannot be justified, stating that Kendall's tau or Spearman's rank should be considered (Bonett & A. Wright, 2000). In addition, the linear dependence of Pearson's r (Helsel & Hirsch, 1992, p. 218) would add considerable time to curating the retrieved samples from respondents. An overview of the considerations between correlation approaches can be found in Table 7.

This thesis will use the Spearman's r because it has comparable robustness to Kendall's Tau, while it is a well-known correlation statistic.

Table 7 Consideration of correlation approaches

		Robustness	**Efficiency**	**Small sample size**	**Relation requirement**
1.	Pearson's Rho (ρ)	-- [a]	++ [b]	++	Lineair
2.	Kendall's Tau (τ)	++	++ [c]	+-	Non-lineair
3.	Spearman's r	++	+- [c]	+-	Non-lineair

[a] Robustness to outliers low. Outliers strongly affect correlation negatively (Croux & Dehon, 2010)
[b] Pearson most efficient at normal distribution only (Croux & Dehon, 2010)
[c] Statistical efficiency remains high for all possible values (0..1) of the population correlation (Croux & Dehon, 2010)

5.8.3   Correlation coefficient descriptors

The meaning or correlation coefficients are a matter of interpretation. A much cited correlation interpretation scale is the one of Cohen, separating correlation coefficients in three discrete steps (Cohen, 1988). However, Evans allows for a more granular approach with five steps (Evans, 1995). In comparison, on the one hand Cohen's approach dictates that any R^2 (i.e. variance that is predictable) of 25% and greater is strong. On the other hand, Evans states that any R^2 of 64% or higher is strong, which for this thesis leaves more room to discriminate between correlation strengths; most notably moderate, strong and very strong. See Table 8 for the different scale used by Cohen and Evans. Also, notice the colour codings that may be used for correlation matrices. In this thesis the sample was on the low side (around 50) to larger correlations will be considered from R = 0.5 and greater.

Table 8 Interpreting correlation

		(Evans, 1995)		**(Cohen, 1988)**	
	Correlation strength	**R**	**R^2**	**R**	**R^2**
1.	Very weak	0 - .19	0 – 4%		
2.	Weak	.20 - .39	4 – 16%	.1 - .3	1 – 9 %
3.	Moderate	.40 - .59	16 – 36%	.3 - .5	10 – 25%
4.	Strong	.60 - .79	36 – 64%	.5 – 1.0	25 – 100%
5.	Very strong	.80 – 1.00	64 – 100%		

5.8.4   Factor analysis: Principal component analysis

The method used to extract factors is Principal Component Analysis (PCA). The reason for using PCA above Principal Axis Factoring (PAF) is that PCA turned more robust than PCA. Indeed, PCA was able to generate factors where PAF failed because of a non-positive definite (NPD)[6]. In essence PAF reduced the number of cases (i.e. data collected from respondents) from the data file to an extent where more variables remained in the analysis than cases existed. For example, the listwise deletion of cases with missing data and pairwise deletion due to linear dependencies could result in less cases in relation to variables remaining for analysis.

Additionally, the usage of orthogonal versus oblique rotation has been deliberated. Oblique rotation allows factors to share loadings among variables while orthogonal rotation does not. This results in oblique rotation showing an increase in factor loadings for some of the variables compared to orthogonal rotation. After testing both varimax (i.e. orthogonal rotation) and promax (i.e. oblique rotation) the results showed that the amount of factors produced were the same and factor loadings were similar. However, varimax was able to more distinctively appoint loadings to variables and less 'noise' was present. With noise is meant that variables that score low with varimax may score a bit higher using promax. However, not enough to consider a variable to be included into a certain factor compared to varimax. High factor loadings remained high with promax. In effect, additional noise was introduced into analysis when using promax, i.e. less distinctive loadings. For this reason varimax was chosen in favour of promax after testing and comparing promax results.

The literature also states that any of the more popular rotation models can be expected to yield the same results (Corner, 2009). Using either varimax or promax is recommended over alternatives like direct oblimin, quartimax and equamax (which are also available in SPSS).

Varimax will be used to rotate the component matrices.

5.8.5   Regression model

Multiple linear regression is used for the regression model. The reason is that this is that multiple independent variables remain after the factor analysis. Therefore, no simple one independent variable (e.g. mechanistic nature of the organization) and one dependent variable (e.g. business demand) solution will be used. Moreover, it is possible that multiple dependent variables will arise after the factor analysis. In such a case the number of regression models presented will be the same as the number of dependent variables found.

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[6] Non positive definite: http://www-01.ibm.com/support/docview.wss?uid=swg21477275

6 Data analysis

This chapter holds the data analysis of the respondents' results. Sub chapters describe a range of information about the quantitative results. The first sub chapter describes the response details, followed by descriptive statistics. Next is described the reliability of the data and what correlations are found. In the final steps of this chapter is explained what factors can be distilled from the data and what linear regression model can be extracted. The chapter finalizes with a conclusion.

6.1 Responses

A total of 626 invites have viewed the questionnaire introduction screen. Of this group, 115 respondents have started the questionnaire (18.4%). Finally, 56 respondents completed the questionnaire (48.7%) (excluding the respondents that do not produce PETs) which makes the response rate 8.9%. However, these responses may contain "n/a" (i.e. not available or not applicable) answers or partial responses and thus the number of responses per question may vary. Besides Viewed, Started and Completed the column Sent in Table 9, Table 10 and Table 11 means that the questionnaire was sent to the respondents. Also, please note that Table 10 contains a 0 (zero) in case the Privacy association did not respond, or responded negatively, to the inquiry to send the questionnaire to their members. A "-" (dash) means it is unknown what the specific value is.

Table 9 Respondents invited via PET lists

	PET lists [c]	**Sent**	**Viewed**	**Start.**	**Compl.**
1.	Privacy Pack	17			
2.	Privacytools.io	80			
3.	C2D2 Privacy Projects	39			
4.	EPIC Practical Privacy Tools	8			
5.	Peng Zhong's Prism Break	30			
6.	PETs found through snowballing	20[b]			
7.	European Cyber Security Group	23			
8.	Stanford PET list	4			
9.	Interviewed organizations (partial list)	7			
10.	Dcypher 2017 (selected organizations)	4[b]			
	Total [a]	232	232	58	39

a. Started: 32 at initial mailing, 26 at reminder. Completed: 22 at initial mailing, 17 at reminder.

b. added in reminder round.

c. See section "5.2.2 Sample frame" for the URLs to the PET lists.

Table 10 Respondents invited via Privacy Associations

	Organization or PET list	Sent	Viewed	Start.	Compl.
11.	PET Symposium (https://petsymposium.org/)	-	25	13	3
12.	IAPP, International Association of Privacy Professionals (International)	-	118	1	0
13.	IAPP Australia/New Zealand	0			
14.	ADPO, The Association of Data Protection Officers (Ireland)	0			
15.	AFCDP, French Association of Data Protection Correspondents	0			
16.	APEP, Asociación Profesional Española de Privacidad (Spain)	0			
17.	DSCI, Data Security Council of India	-	21	7	3
18.	GDD, German Association for Data Protection and Data Security	0			
19.	IMM, The Institute of Information Management (IIM) Africa	0			
20.	CPO, Korea CPO Forum	0			
21.	NGFG, Nederlands Genootschap van Functionarissen voor de Gegevensbescherming (Netherlands)	160	(60) [b]	(27) [b]	(2[a]) [b]
22.	UK Data Protection Forum	0			
23.	PvIB, Platform voor InformatieBeveiliging (Netherlands)	0			
	Total	-	164	21	6

a. Of 13 completed responses, 11 members did not produce PETs (which aborts the questionnaire), only 2 respondents produced PETs which is the number shown. Moreover, 1 respondent completed the questionnaire in full, another respondent completed only a few questions.

b. Figures between parentheses: due to late response and only counting 1 full response, excluded in the research due to time constraints.

The respondents' statistics in Table 10 show parentheses around the figures of NGFG. The explanation is that the results were received late during the project, and more importantly, only one full response was recorded. Because of this it was considered not time efficient to redo all the analysis work. The respondent statistics for NGFG have not been added to the grand total in Table 11.

Table 11 Respondent reaction via generic questionnaire link.

	Organization or PET list	Sent	Viewed	Start.	Compl.
24.	Generic shared link [a]	-	230	36	11
	Grand total of all respondents		626	115	56

a. Viewed: 192 at initial mailings, 38 at reminder. Started: 23 at initial mailing, 13 at reminder. Completed: 8 at initial mailing, 5 at reminder.

Completed questionnaires may contain n/a responses yielding fewer fully answered questionnaires in total.

6.2 Descriptive statistics

In the descriptive statistics appendix, Appendix D: Descriptive statistics, is shown the table with responses per question (excluding "n/a", i.e. not available or not applicable), range, minimum, maximum, mean, standard deviation, variance, skewness and kurtosis. The average standard deviation among questions is calculated at 1.760. Apparently, especially category D (i.e. Design values) holds questions with larger standard deviations. Although no conclusions can be built upon these numbers, they do serve as a first hunch (Verschuren & Hartog, 2005) towards building our model. For instance, this might indicate that respondents differ more on design value issues than on issues in other categories.

6.2.1   Produced PET products and services

The most prevalent PET context used to answer the questionnaire has been VPN services (18%) followed by Tor elated services (17%). Also Email related PETs (12%) and Cloud services (9%) have been used to answer the questionnaire. Contributions from PETs that are represented 7% or less are shown in Table 12. Some PET products/service that were described by respondents fall in multiple categories. The number mentioned types in Table 12 can therefore exceed the number of responses (N=56).

Table 12 Produced PET products and services (N=56)

Product/ service	Number of responses contain this type	% of responses
VPN	15	18%
Tor related	14	17%
Email	10	12%
Cloud	7	9%
Secure storage	6	7%
Tracking protection	5	6%
File sharing & collaboration	5	6%
Communication	4	5%
Browser extension	4	5%
Social media	3	4%
Protocol	3	4%
Remainder [a]	9	9%

a. The remainder of PET products/services are: monitoring, firewall, blockchain, messaging, Operating System, Peer-to-Peer and GDRP related.

Table 12 shows that the generalizability of the research in this thesis is mainly based on secure infrastructure (i.e. VPN, Tor, protocol) and communication and data storage (i.e. email, cloud, secure storage, file sharing, communication). These categories account for over 65% of all responses. Hence, the chosen context of private communication and data storage for the research can be upheld.

The questionnaire question used to generate this statistic is [FA01M] "Please describe the main Privacy-enhancing product/service of your organization (e.g. VPN, secure email, self-hosted cloud storage, ad blockers, etc) or the PET that you have worked on in the past."

6.2.2   Total number of staff within organization

The European Union defines Small and Medium-sized Enterprises (SME's) as micro (1-9 employees), small (10-49 employees) and medium (50-249 employees). Large enterprises contain 250 employees or more. The same categorization is used in thus statistic. However, not all organizations need to be legal entities, thus the term staff is used.

The majority of respondents work in small-sized or smaller organizations, as in 74% of the cases. Medium-sized organizations count for 11% of the respondents and the rest (15%) are large organizations.

Number of staff in organization

Figure 5 Organization size in relative figures (N=46)

These results are important to take notice of because this means that the generalizability of the research is limited to smaller organizations as shown in Figure 5. The absolute division in respondent's organization size is shown in Table 13. Please note that not all respondents completed the questionnaire and thus the total number of responses that completed this question is 46. The question used for this statistic is [FB11M] "Total number of employees/ staff of organization; or if you do not form a legal entity, your organization is the total number of people involved with the PET".

Table 13 Company size in absolute figures (N=46)

Number of staff	Organization size[7]	Responses
1 – 9	Micro	28
10 – 49	Small	6
50 – 249	Medium	5
>= 250	Large	7

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[7] http://ec.europa.eu/growth/smes/business-friendly-environment/sme-definition_nl

6.2.3   Main source of revenue

The majority of primary revenue generated in organizations is generated from products (22% of the organizations) and service (20% of the organizations), totalling 42% of the organizations. Besides offering products and services, 15% of the organizations generate their primary revenue from consulting and a minority generates revenue from licensing (7%). 15% of organizations do not generate revenues and have no budget to spend. See Figure 6.

Peculiar is the category "Other" which accounts for 22%. From the open question field offered to respondents it can be seen that most organizations revert to donations and grants. However, revenue is defined as income generated from sales. The figure may originate from the fact that some organizations work with budgets (that are comprised of donations and grants) because they are a non-profit organization without doing any sales.

The main source of revenue statistics is based on question [FB13M] "Main source of revenue. Or if you are a non-profit organization, main source of budget spending".
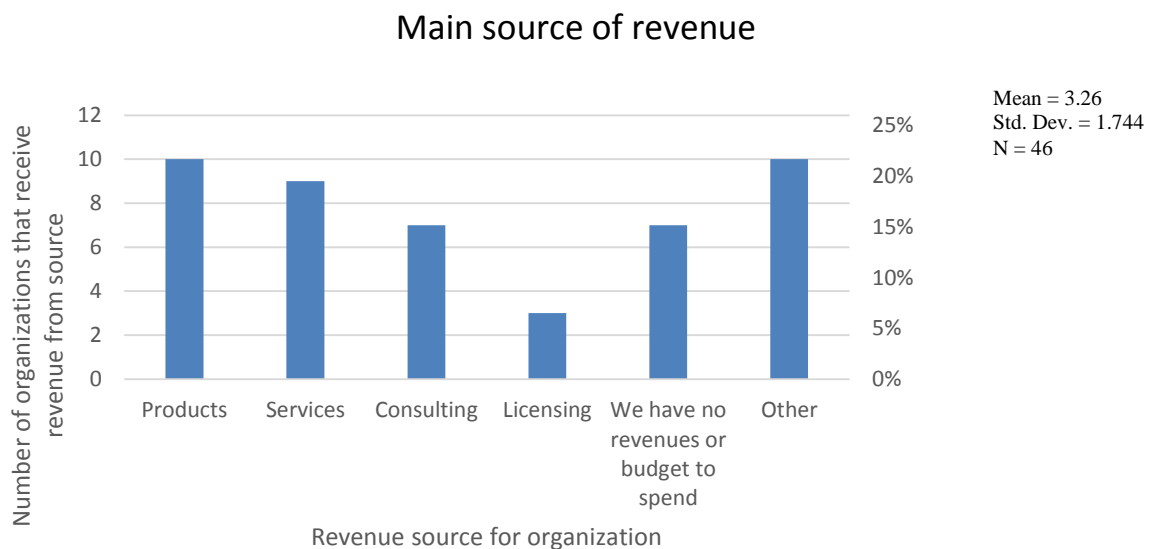
Figure 6 Main source of revenue (N=46)

6.2.4   Base of operations of organization

The base of operations (e.g. where development and decision making process originate from) of organizations is primarily considered to be the current location of the organization. However, some organizations change the base of operations over time. To take this into consideration respondents were asked to state the country where most of the development has taken place over time to have a more realistic view of the base of operation of an organization.

Most of the respondents (67%) have their base of operations in Europe. Seven respondents designated the base of operations as "Europe" in general. Specific countries include the Netherlands (7), Germany

(5), Switzerland (4), Austria (2) and France (2). Countries that generated only one response were: Belgium, Hungary, Iceland, United Kingdom and Sweden.

The second largest (22%) group of respondents state that their main base of operations originates from North America, including the United States of America (7) and Canada (3).

Countries that generated only one response in Oceania and Asia were: Australia, New Zealand and India. Two respondents stated that the primary base of operations of the organization is "Worldwide".

Privacy-Enhancing Technologies can be adopted worldwide because software can easily be distributed worldwide at almost zero marginal costs. This argument could emphasize full generalizability to the results. However, (latent) issues may be different between geographically different regions. Because of this, a more cautious statement would be that the results will be generalizable to Europe and North America.

The distribution of main base of operations can be viewed in Table 14.

Table 14 Base of operations of organizations (N=46)

Organization is based in	Amount of organizations	% or organizations
Europe	31	67%
North America	10	22%
Oceania	2	4%
Asia	1	2%
World	2	4%

The question used to generate this statistic is [FC12M] "In which country is your organization mainly based (i.e. workplace)? Or if that has changed over time, in what country did most development and management decisions take place?"

6.2.5 Used license for PET product/service

Organizations produce their PET product/service under a certain license. This can vary from completely proprietary to completely open source and any combination in between. The descriptive statistics show that the overwhelming majority of organizations produce completely open source PET products and services. Only a small portion of organizations produce completely proprietary PET solutions. Finally, about 18% produce PETs that use a license that contain both proprietary and open source components. Figure 7 shows a schematic representation of license distribution.

Because of this statistic, the results of this research may be skewed towards the responses and mind-set of organizations that produce fully open source PETs. Similarly to section 6.2.2 , the research results may primarily be generalizable to smaller organizations, that produce fully open source PETs.

Used license for PET product/ service

Completely proprietary
11%

Mixed proprietary and
open source
11%

Almost completely open
source
7%

Completely open source
71%
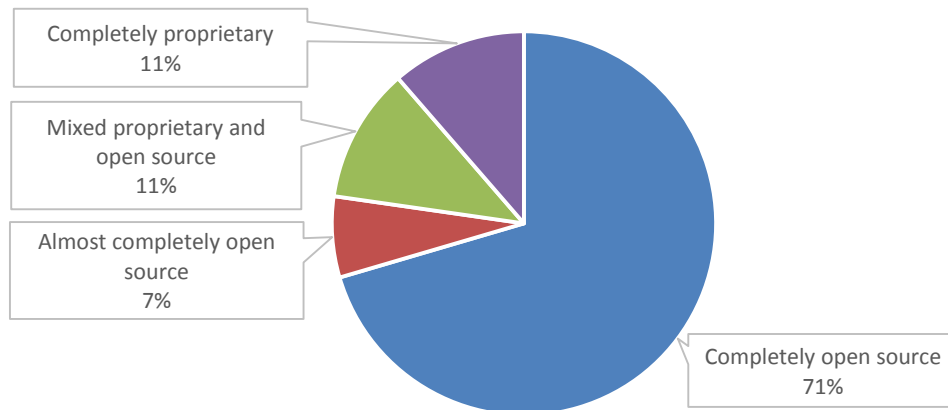
Figure 7 Used license for PET product/service (N=44)

The question used to generate this statistic is [BD19M_A] "Under what license is your PET product/service created?"

6.2.6   PET producing experience

The collective PET producing experience of all 44 organizations that have responded to this question is 487 years. This means that the average experience per firm is 11 years and 1 month.

When the outlier is removed (an organization that has 69 years of PET producing experience), the cumulative experience in years becomes 418 years with an average of 9 years and 9 months. In this case the mode is 10 to 14 years of PET producing experience.

It can be safely stated that the majority of organizations have considerable experience with PET production. 33 out of 44 organizations have five years or more experience producing PETs. It is safe to generally state that an organization that survives the first five years of entrepreneuring cannot be considered a start-up anymore. Indeed, most organizations in this research have been able to survive for a longer duration. This importance of this statistic is that the research results can be placed in a successful entrepreneurial context, i.e. organizations are able to survive for a prolonged period. The distribution of PET producing experience can be viewed in the histogram of Figure 8.

PET producing experience per organization

Mean = 11.07
Std. Dev. = 10.906
N = 44

Outlier removed: 69
Mean = 9.72
Std. Dev. = 6.326
N = 43
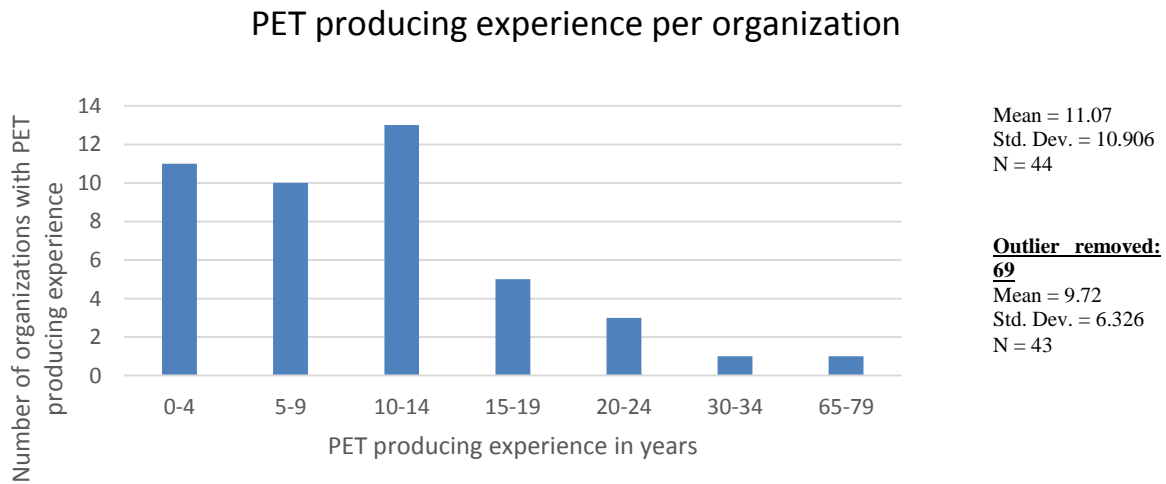
Figure 8 PET producing experience per organization histogram (N=44)

The questionnaire statement used to generate this statistic is [FE09M] "PET producing experience of your organization (in years)."

6.2.7   Amount of staff involved with PET R&D

PET producing organizations have a certain amount of staff working on PET Research & Development (R&D). Most organizations (48%) have 80 to 100% of their staff working of PET R&D. 25% of organizations have 0 to 19% of their staff working on PET R&D. The remaining 27% of the organizations have 20 to 79% of their staff working on PET R&D. The results are shown in Figure 9.

The importance of this statistic is that this may again emphasize that the results are only generalizable to smaller organizations, like stated in sections 6.2.2 and 6.2.5 . The reason for this argument is that often smaller organizations show more organic organizational properties (i.e. less standardisation and formalisation) (Schilling, 2012, p. 212) that allows staff to have multiple roles. This introduces agility and is often reserved for smaller organizations.

Staff involved with PET R&D
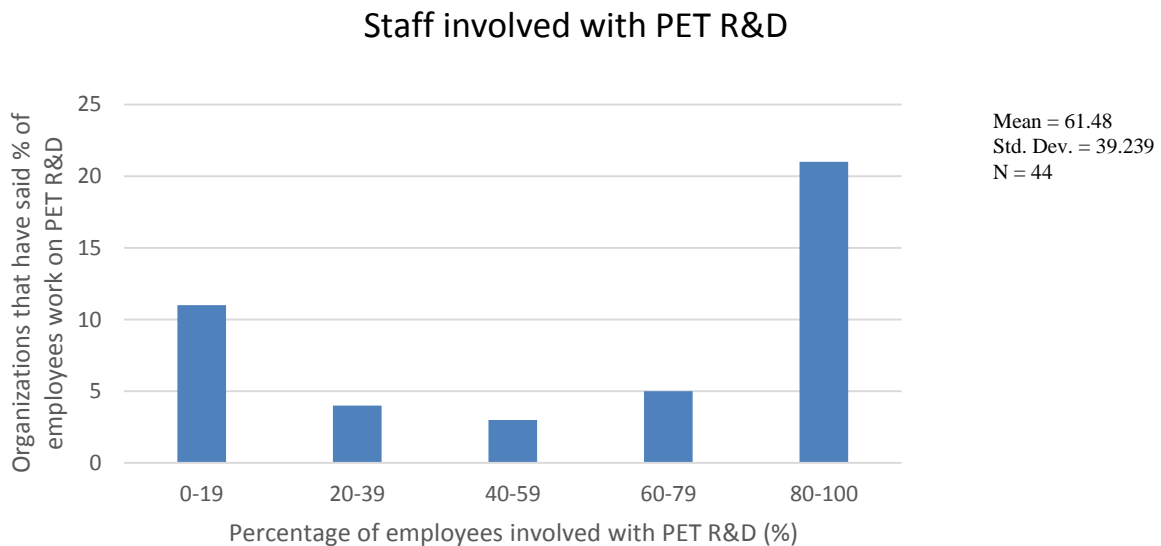
Figure 9 Staff involved with PET R&D (N=44)

The question used to generate this statistic is [FE10M] "Amount of staff involved with PET R&D (in %); for small non-profit open-source projects this is most likely '100' (%)."

6.2.8   Annual revenue in the last year and growth

Of the organizations that filled in the questionnaire 22% generate no revenue at all. The European Union[8] defines micro organizations as generating less than €2 million revenue per year; 67% of the organizations fall into this category (excluding the zero revenue organizations). The 67% is divided over three sub categories shown in Figure 10.

Only 5% of the organizations can be designated as small organizations (€2M to €10M) and 6% can be designated as medium-sized or large organizations (> €10M).

A total of 89% of the organizations is micro-sized. This again emphasizes that most respondents work for (very) small organizations. The implication of this is that the generalizability of the findings are limited to smaller PET producing organizations.

The question used to generate this statistic is [FB12M] "Annual revenue in the last year (in Euro). Or if you are a non-profit organization, annual budget."

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[8] http://ec.europa.eu/growth/smes/business-friendly-environment/sme-definition_nl

Annual revenue in the last year (in €) for organizations
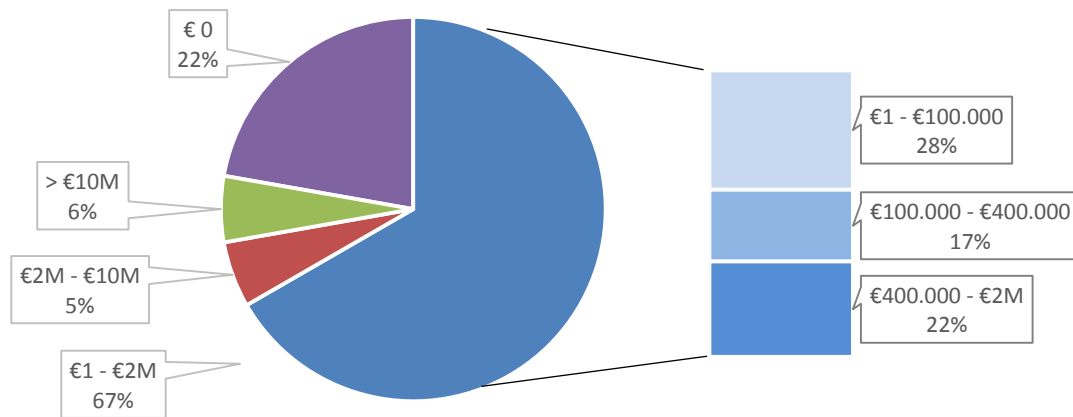
Figure 10 Annual revenue in the last year (in €) for organizations (N=36)

Another descriptive statistic is the revenue growth of organizations. Figure 11 shows that 12 organizations have 0% revenue growth. Seven organizations have 1 to 49% revenue growth. These categories together account for 76% of the organizations. There is one outlier, an organization having 300 to 349% growth (which is probably a start-up given the high growth).

This statistic mainly shows that almost half of the organizations have no growth at all (12 out of 25). This strongly hints at the fact that nearly half of the organizations is not commercial in nature. However, the rest of the organizations (except one) does experience revenue growth. Hence, the generalisability of the research is limited to non-profit like organizations (maybe even small projects without a legal entity) and commercial organizations.

Annual revenue growth
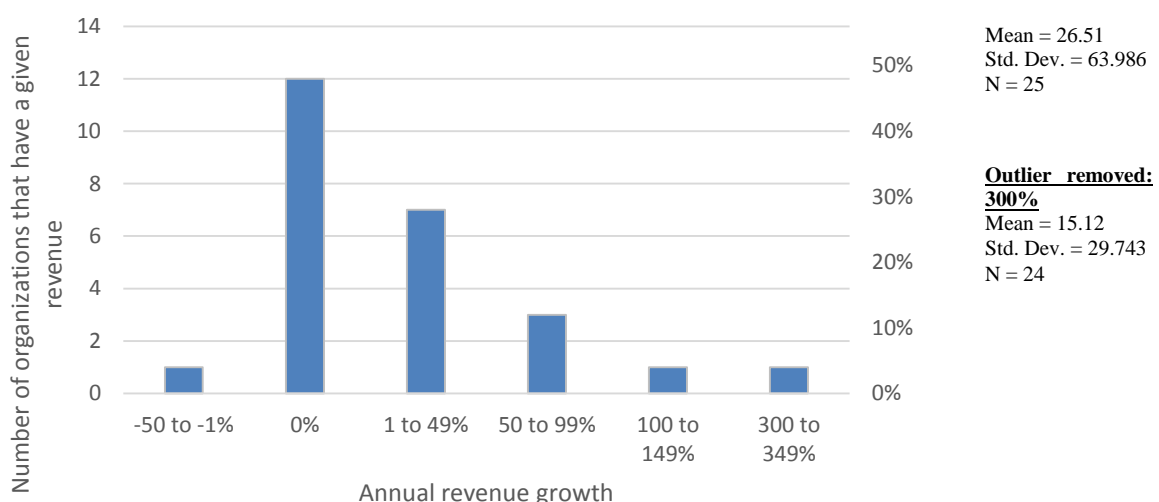
Figure 11 Annual revenue growth (N=25)

The question used to generate this statistic is [FB14O] "Annual revenue growth (in %) as an average of the last 3 years. Or if you are a non-profit organization, annual budget growth (in %)."

6.2.9   Most important funding options

Respondents have been asked what type of funding option is most important to the organization, excluding revenues from sales & subscriptions. Table 11 shows the most important funding options[9] to organizations that have been selected by respondents.

The predominant type of funding is bootstrapping (30%) followed by subsidies, grants and seed money (20%). One-time donations is considered the most important funding type in 13% of the cases.

What is most interesting to see is that, even though, the European Union puts cyber security and privacy innovation high on the agenda, the number of organizations that see subsidies, grants and seed money as the most important source of funding is only 20%. 30% of the organizations are either not eligible or unable to find public support.

Funding option	Used by # of organizations	% or organizations
Bootstrapping (i.e. your own money)	14	30%
Company sponsors	4	9%
Donations, One-time micro (e.g. Bitcoins, PayPal)	6	13%
Donations, Recurring micro (e.g Flattr)	1	2%
Equity from shareholders	2	4%
Membership platform (e.g. Patreon)	1	2%
Non-profit support (e.g. Mozilla Foundation)	1	2%
Subsidies, Grants (e.g. OTF), Seed Money	9	20%
Venture capital	1	2%
We don't get any funding	4	9%
Other	3	7%

Figure 12 Most important funding options for organizations (N=46)

The question used to generate this statistic is [B10M] "What is the most important funding option that your organization utilizes for PET projects, excluding revenues from sales & subscriptions?"

6.2.10   The need for monetary public support

In addition to the previous statistic, the question is whether there is a need for public support. Are organizations overall satisfied with the current funding options or is there a need for public monetary support? Figure 13 shows that the majority (50%) of organizations feel that public monetary support is needed to support PET development. Only 36% of the organizations think no public monetary support is needed. 14% of the organizations remain neutral about public monetary support.

It could be said that the current availability of funding options if not sufficient. There is a call for public monetary support which may originate primarily from organizational that currently utilize bootstrapping

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[9] The questionnaire presented more options. However, some options were not selected by respondents. These options include: 1. Angel, 2. Bank loan, 3. Crowd funding, Reward-based (e.g. Kickstarter), 4. Donations, One-time large (e.g. Bitcoins, PayPal), 5. Friends and family.

for example. An increase in availability and/or ease of acquiring public monetary support may indeed stimulate the adoption and diffusion of PETs.

Whether PET development needs public monetary support
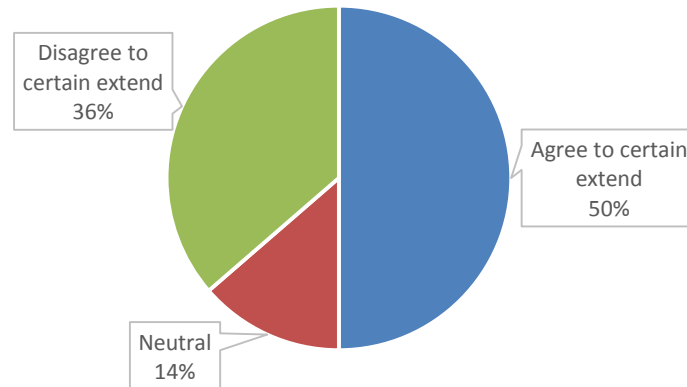
Figure 13 Whether PET development needs public monetary support (N=44)

The question used to generate this statistic is [B01M_G] "Our PET product/service needs monetary public support to develop and thrive."

6.2.11   Abilities of respondents

The questions in the questionnaire are considered to be easy to understand by respondents as shown in Figure 14. 86% of the respondents found the questionnaire easy to understand. Only 7% found the questions neither difficult nor easy to understand. And 7% found the questionnaire questions difficult to answer to a certain extent. That most respondents easily understood the questionnaire questions asserts that the validity of the research is likely not to be negatively affected by a lack of understanding the questionnaire questions. See Figure 14 for an easy overview.

The feedback of respondents has been that some questions were difficult to answer because some questions are seem to be directed solely at for-profit organizations (i.e. businesses). Therefore, some of the questions were deemed irrelevant by a selection of respondents. Nevertheless, earlier statistics show that more than 14% of the organizations do not generate revenue (section 6.2.8). Still, business-oriented questions seem relevant to at least a subset of non-revenue generating participants.

Another respondent statistic is whether respondents see themselves as knowledgeable concerning PETs. The question was asked in relation to colleagues. Of the respondents, 84% find that they have comparable or better knowledge about PETs than colleagues. Again, this high value asserts that the research is likely not to be negatively affected by a lack of knowledge about PETs. See Figure 15 of an easy overview.

The questions were easy to understand
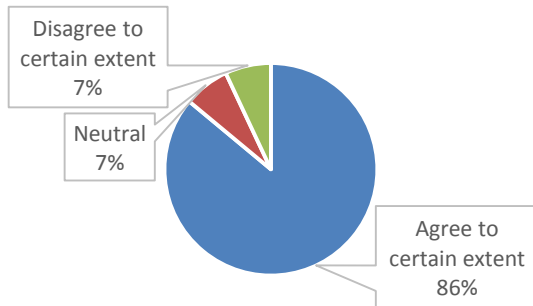
Figure 14 The questions were easy to understand

The respondent's knowledge about PETs is high
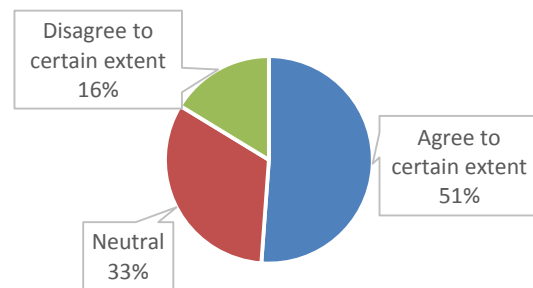
Figure 15 The respondent's knowledge about PETs is high

The questionnaire question used for the statistic shown in Figure 14 is based on [G_UNDERSTAND_A] "The questions in this questionnaire were easy to understand." The questionnaire question used for the statistic shown in Figure 15 is based on [G_UNDERSTAND_B] "My knowledge about PETs compared to my colleagues is high."

Respondents have a certain role within their organization. Most respondents are lead developer (30%), followed by Chief Executive Officers (18%), Chief Technology Officers (11%) and roles that include non-executive management (11%), and vice president and director roles (7%). Other notable job positions are VP's and directors (7%), and legal and policy (7%).

These categories show that at least 84% of the respondents have an executive, leading or management role that allows for both an overview of operations and mostly be involved in PET development. This asserts that the research results are likely not negatively affected by respondents that have no overview of what happens in the organization.

Table 15 Job positions of respondents (N=40)

Job position includes	Respondents having job position [b]	% of respondents
Lead developer	13	30%
CEO or owner	8	18%
CTO	5	11%
Manager	5	11%
VP's and directors	3	7%
Legal and policy	3	7%
Remainder [a]	7	16%

a Includes job positions that entail: designer (2), volunteer (2), consultant (1), developer (1) and marketing (1) related
b Cummulative figure is 44, which is larger than N=40. Some respondents have multiple job positions.

Respondents have also been asked what their and their colleagues' highest completed education is. This question was asked to have a better understanding of whether PET development requires higher education (i.e. Bachelor and higher). It must be noted that the used questionnaire question may give incentive to respondents to answer the question with solely their own educational background. Another limitation of the used question is shown in the previous statistic: job positions. Most respondents have a job position with a managing role which often necessitates a higher education.

This statistic should therefore be taken with a grain of salt. Concerning the question whether PET development requires a certain educational level. However, for this research it is relevant to note that respondents mostly have a scientific background (i.e. Bachelor and higher) that accounts for 91% of all respondents. Consequently, they may have more affinity with methodological thinking which may result in more apt responses to the questionnaire questions and thus yield a high quality of answering.
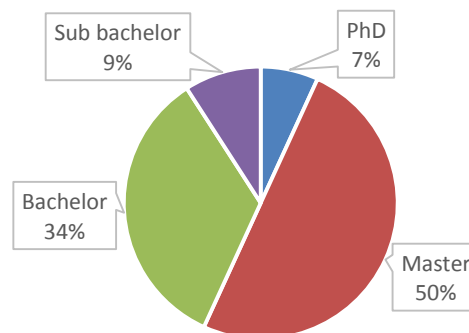
Figure 16 Respondent and colleagues' education

The questionnaire question used for the statistic is [FE11M] "I and most of my colleagues have completed... (highest degree completed by most people)"

6.2.12   Hypothesis testing

Section 6.2.9 6.2.3 have revealed what funding options organizations use most.

Hypothesis 4

Hypothesis 4 testing: "The most important funding option are donations."

30% of the organizations use Bootstrapping (i.e. your own money) as the primary source of funding.

20% of the organizations utilize Subsidies, Grants (e.g. OTF) or Seed Money as the primary source of funding.

13% of the organizations use one-time micro donations (e.g. Bitcoins, PayPal) and only 2% use recurring micro donations (e.g Flattr) for a combined 15%. This is much less than the two leading funding options.

Because of these statistics the hypothesis is rejected.

6.2.13   Conclusion

The descriptive statistics have revealed both some affirmations and some limitations of the questionnaire results. First, it is confirmed that most organizations that responded produce data communication and storage PETs (section 6.2.1). Second, the research seems limited in its ability to generalize beyond small organizations. Most organizations that responded are either micro or small organizations. An aggregation of responses in different sections confirm this (section 6.2.2 , 6.2.7 , 6.2.8). Third, respondents understood the questions in the questionnaire well, they are knowledgeable about PETs and are highly educated (section 6.2.11). Fourth, the research also seems limited to mostly European and North American responses (section 6.2.4). It is unknown whether cultural issue between continents may impact the results. In any case, generalizability of the research is considered to be legitimate for at least Europe and Northern America. Sixth, most organizations have no revenue growth at all (section 6.2.8), they depend mostly on bootstrapping (6.2.9) and most organizations consider public monetary support necessary (6.2.10). It may be that funding options offered by e.g. the European Union are not able to reach organizations that actually need it. In which case these organizations resolve to e.g. bootstrapping.

6.3 Reliability of the data

Cronbach's alpha is a measure of internal consistency, or scale reliability. In other words, whether a set of items are closely related as a group. The Cronbach's alpha is .842 and the Cronbach's alpha on standardized items is .869. The number of items (N) is 54. A Cronbach alpha of $> .8$ is considered good reliability. For a complete overview per item see "Appendix E: Reliability".

6.4 Correlations

Correlations may give insights into questions (variables) that move together, i.e. when one variable increase that other variable increases or decreases with a certain amount. For example, when *guidance by law* increases, *guidance by PET authorities* also rises with a certain amount. Using Spearman's r we want to find a list of correlations and discuss what these correlations may mean. Correlations are shown in the context of factor analysis in the next sub chapter.

6.5 Factor analysis and correlations

This sub chapter explains how the factor analysis has been done on the five categories.

6.5.1   Dependent category A: exploratory phase

Category A is the category *Adoption & diffusion* which is a dependent category (i.e. we will use the items in this category as dependent variables). First, the most direct questions to adoption & diffusion

(i.e. all variables starting with A) were complemented by the scale questions from Moore's adoption & diffusion model (Moore & Benbasat, 1991). See .

Table 16 with the mapping of Moore standard scale questions to adoption & diffusion, and the code used.

Table 16 The standard Moore scales used to determine adoption & diffusion of a PET (Moore & Benbasat, 1991)

	Definition	**Code**
1. Voluntariness	Whether a user is forced to use the PET. **PET question**: The Privacy-enhancing Technology (PET) product/service we produce is very visible to the market.	D01M_M
2. Relative advantage	Gives user greater control over what they want to do. **PET question**: Our PET product/service gives users more control over their personal data processing.	D01M_D
3. Compatibility	Translated to *interoperability* due to being more appropriate (i.e. systems do not necessarily need to be compatible, but should be able to exchange information with each other). **PET question**: PET interoperability with other PETs is important. **PET question**: Our PET product/service has high interoperability with other PETs.	D01M_Q, D01M_R
4. Image	Removed as per feedback of Alexandra Michota (ENISA), because image plays less or a role with PETs.	-
5. Ease of use	Whether a PET is perceived as easy to use by users. **PET question**: Customers find our PET product/service easy to use.	D01M_B
6. Result demonstrability	Whether a user would be able to easily (i.e. without difficulty) explain what a PET does. **PET question**: Users would have no difficulty telling others about the results of using our PET product/service.	A02M_E
7. Visibility	Whether a PET is visible to a user. That a user is being confronted with the existence of a PET. **PET question**: The Privacy-enhancing Technology (PET) product/service we produce is very visible to the market.	A02M_A
8.Triability	That a user is able to properly try out the PET before deciding to use it (or purchase is). **PET question**: Users are able to properly try out our PET product/service, before deciding whether to use it.	D01M_C

Furthermore, the question about ease of use should also measure the usefulness of the PET product/service (Lund, 2001). The reason to only use question about ease of use ("Customers find our PET product/service easy to use") is because we find that a PET producer will always think the PET they develop is useful or they would not put their time into the project. Also, usefulness would drive satisfaction and satisfaction would be strongly related to actual or predicted use thus satisfaction is considered a good predicator to adoption (Lund, 2001).

Table 17 PCA of Adoption & diffusion category with A questions and Moore scale questions

	Component				
	1	2	3	4	5
[A02M_A] The Privacy-enhancing Technology (PET) product/service we produce is very visible to the market.	0.650	0.304	0.359	0.133	-0.163
[A02M_B] The demand for our PET product/service by private consumers is high.	0.112	0.850	0.128	0.078	0.114
[A02M_C] The demand for our PET product/service by private businesses is high.	0.819	0.327	-0.045	-0.201	-0.108
[A02M_D] The demand for our PET product/service by public organizations is high.	0.887	0.018	-0.028	0.090	-0.055
[A02M_E] Users would have no difficulty telling others about the results of using our PET product/service.	0.249	0.634	0.005	0.471	0.037
[A02M_F] We have noticed a growth in use or sales of the PET product/service in the last year.	0.297	0.638	0.358	-0.064	-0.107
[D01M_A] Customers are satisfied with our PET product/service.	0.142	0.154	0.276	0.830	-0.066
[D01M_B] Customers find our PET product/service easy to use.	-0.064	0.143	-0.278	0.856	-0.020
[D01M_C] Users are able to properly try out our PET product/service, before deciding whether to use it.	-0.061	0.182	0.037	-0.072	0.936
[D01M_D] Our PET product/service gives users more control over their personal data processing.	-0.187	0.678	-0.049	0.258	0.189
[D01M_M] Users are required to use our PET product/service by their superior (e.g. a boss) or by law.	0.680	-0.361	0.066	0.229	0.300
[D01M_Q] PET interoperability with other PETs is important.	-0.218	0.091	0.853	-0.013	0.102
[D01M_R] Our PET product/service has high interoperability with other PETs.	0.314	0.089	0.843	-0.002	-0.042

Some interesting findings can be extracted from the questions placed together in one factor. First, some of the questions correlate very strongly (> 0.8; emphasized in blue). For instance, the variables [A02M_C] *Private business demand* and [A02M_D] *Public organizations demand* correlate strongly. The factors can be labelled as follows:

Factor 1: Demand by businesses

Factor 2: Demand by consumers

Factor 3: Level of interoperability, overall

Factor 4: Satisfaction and usage, overall

Factor 5: Triability, overall

Not all questions have enough distinctiveness to be placed in a separate factor. For instance, we see that two questions are placed in factor 1 (i.e. *demand by businesses*) and three questions are placed in factor 2 (i.e. *demand by consumers*) that do not get their own factor meaning that they highly correlate with the factors these questions are placed in. Luckily, is seems that no questions belong to multiple factors (i.e. that the loading given to a question is above roughly 0.5 or below -0.5).

Observing from a Spearman correlation perspective, correlations within the same category (e.g. A or D) are potentially less of a problem because these questions will probably be positioned in the same factor during factor analysis. For example, this is shown in

Table 17 for [A02M_C] private businesses and [A02M_D] public organizations. In general, any correlation within the same category (denoted by the red dashed boxes in Table 18) may not be a problem for (multi)collinearity in the factor analysis later. Either collinearity or multicollinearity either between independent variables or between dependent variable and independent variables. However, correlations between questions that are present in different categories may potentially be a problem (e.g. causing (multi)collinearity later in the linear regression). Correlation between questions of different categories is in Table 18 denoted by a question correlating within a red dashed frame with a question outside the red dashed frame. The diagonal may be ignored because a question will always fully correlate with itself. Also, any question that correlates weaker than 0.5 (i.e. moderate) is not shown in the correlation matrices. Find the full matrix of correlations (both Spearman's r and Pearson's rho), including significance per correlation and observations (i.e. N) in "Appendix F: Correlation, Adoption & diffusion and Moore's scale questions", p. 144.

To compare the factor analysis (i.e. PCA) with the correlation matrix, Table 17 shows that [A02M_E] *Result demonstrability* is placed together with [A02M_F] *We have noticed a growth in use or sales* together with the question that has the highest loading, namely [A02M_B] *Demand by private consumers*. However, when we look at Table 18 we see that only A02M_E has a correlation larger than 0.5 but this is with question [D01M_A] *Customer satisfaction*. Indeed, no correlation greater than 0.5 (i.e. moderate) exists between any of the questions A02M_B, A02M_E and A02M_F (and is thus not displayed in this condensed correlation matrix of Table 18).

Table 18 Spearman correlation matrix: Adoption & diffusion category with A questions and Moore scale questions

	[A02M_A]	[A02M_C]	[A02M_D]	[A02M_E]	[D01M_A]	[D01M_B]	[D01M_M]	[D01M_Q]	[D01M_R]
[A02M_A] The Privacy-enhancing Technology (PET) product/service we produce is very visible to the market.	1.000								
[A02M_C] The demand for our PET product/service by private businesses is high.	.510**	1.000							
[A02M_D] The demand for our PET product/service by public organizations is high.	.502**	.766**	1.000						
[A02M_E] Users would have no difficulty telling others about the results of using our PET product/service.	.299*	0.175	0.196	1.000					
[D01M_A] Customers are satisfied with our PET product/service.	.420**	0.227	0.257	.550**	1.000				
[D01M_B] Customers find our PET product/service easy to use.	0.163	0.113	0.184	.459**	.545**	1.000			
[D01M_M] Users are required to use our PET product/service by their superior (e.g. a boss) or by law.	.385*	.515**	.570**	0.002	0.149	0.181	1.000		
[D01M_Q] PET interoperability with other PETs is important.	0.264	0.036	-0.011	0.139	0.226	-0.124	-0.004	1.000	
[D01M_R] Our PET product/service has high interoperability with other PETs.	.488**	0.227	0.257	0.278	0.237	-0.165	0.202	.688**	1.000

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

Spearman's r is able to find correlations when the relation is non-linear. For comparisons sake, the Pearson's rho (i.e. linear relations) correlation matrix is also included in Table 19. In contrast to Spearman's r correlation, Pearson's rho correlation shows that only [A02M_D] *Public organizations demand* correlates moderately strong (r = 0.566) with [D01M_M] *Involuntary use*. Pearson's rho correlation will not be used any further but the matrix shows that both less and weaker correlation are found due to less robustness (i.e. finding only linear correlations).

Table 19 Pearson correlation matrix: Adoption & diffusion category with A questions and Moore scale questions

	[A02M_A]	[A02M_B]	[A02M_C]	[A02M_D]	[D01M_A]	[D01M_B]	[D01M_M]	[D01M_Q]	[D01M_R]
[A02M_A] The Privacy-enhancing Technology (PET) product/service we produce is very visible to the market.	1								
[A02M_B] The demand for our PET product/service by private consumers is high.	.498**	1							
[A02M_C] The demand for our PET product/service by private businesses is high.	.578**	.520**	1						
[A02M_D] The demand for our PET product/service by public organizations is high.	.544**	.369**	.783**	1					
[D01M_A] Customers are satisfied with our PET product/service.	.419**	0.289	0.186	0.253	1				
[D01M_B] Customers find our PET product/service easy to use.	0.223	0.284	0.138	0.185	.633**	1			
[D01M_M] Users are required to use our PET product/service by their superior (e.g. a boss) or by law.	.411**	0.139	.480**	.566**	0.196	0.264	1		
[D01M_Q] PET interoperability with other PETs is important.	0.164	0.134	-0.011	-0.114	0.129	-0.046	0.006	1	
[D01M_R] Our PET product/service has high interoperability with other PETs.	.398**	0.108	0.207	0.234	0.134	-0.146	0.212	.637**	1

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

Based on these findings, it could be said that the strongest correlations (r > 0.6) fall within the same category and thus no further actions is needed. However, a further iterative process could be followed trying to fit also moderately correlating variables (0.4 < r < 0.6) together in one category. For instance, [A02M_F] *We have noticed a growth in use or sales* correlates with [D01M_A] *Customer satisfaction* and in turn [D01M_A] correlates with [D01M_B] *Ease of use* (r = 0.550). Both D01M_A and D01M_B could be included in the dependent *Adoption &diffusion* category (i.e. category A). In such a case the rest of Moore's adoption & diffusion scale questions will be used in dependent categories.

6.5.2 Dependent category A: decisive phase

First we have a look at the Principal Component Analysis (PCA) of the most direct questions that ask about the current demand of the Privacy-Enhancing Technology.

Table 20 Principal Component Analysis for current demand of PETs (N=52)

	Component
	1
[A02M_B] The demand for our PET product/service by private consumers is high.	0.719
[A02M_C] The demand for our PET product/service by private businesses is high.	0.933
[A02M_D] The demand for our PET product/service by public organizations is high.	0.870

Table 20 shows that only one factor is extracted. All variables (i.e. questions) load highly on the one factor extracted. Additionally, no rotation can be executed on the factor analysis because there is only one factor. Table 21 shows that 71.5% of the variance is explained by the one factor. However, we are unable to meaningfully label the factor, other than a generic label "demand".

Table 21 Amount of variance explained by three variables

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	2.145	71.500	71.500	2.145	71.500	**71.500**
2	0.664	22.129	93.629			
3	0.191	6.371	100.000			

As displayed in Table 22, including all category A variables I the factor analysis yields a meaningful distinction between factors. Indeed, there seems a distinction between consumer demand on the one hand, and private businesses and public organizations on the other hand. Another interesting observation is that it could be said that most respondents don't see a large difference between business and public organizations. Therefore, the demand in factor 1 will be named "Business demand". The three additional variables added load strongly on either factor 1 or two. While this is in essence a good result, for the independent variables this is less of an issue because in the linear regression model either one or the other factor will be used as an independent variable, but not both at the same time (mutual exclusive use).

Table 22 Principal component analysis of variables in category A

	Component [a]	
	1	2
[A02M_A] The Privacy-enhancing Technology (PET) product/service we produce is very visible to the market.	0.667	0.467
[A02M_B] The demand for our PET product/service by private consumers is high.	0.202	**0.855**
[A02M_C] The demand for our PET product/service by private businesses is high.	**0.867**	0.256
[A02M_D] The demand for our PET product/service by public organizations is high.	**0.912**	0.049
[A02M_E] Users would have no difficulty telling others about the results of using our PET product/service.	0.102	0.768
[A02M_F] We have noticed a growth in use or sales of the PET product/service in the last year.	0.214	0.675

a. green: 0.6 < r < 0.8; blue: r > 0.8;

The two factors explain 69.813% of the variance (see Table 23). The KMO Bartlett's test is .703.

Table 23 Cumulative variance explained by factors by category A

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	3.069	51.147	51.147	3.069	51.147	51.147	2.126	35.440	35.440
2	1.120	18.666	69.813	1.120	18.666	69.813	2.062	34.373	**69.813**
3	0.760	12.674	82.487						

The variables used to define the factors in Table 22 are highlighted in bold.

Factor 1: Business demand

Factor 2: Consumer demand

6.5.3   Independent categories B to E

6.5.3.1   Category B

The four factors explain 68.823% of the variance (see Table 24). The KMO Bartlett's test is .579.

Table 24 Cumulative variance explained by factors by category B

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	3.988	33.236	33.236	3.988	33.236	33.236	2.719	22.656	22.656
2	1.759	14.661	47.897	1.759	14.661	47.897	2.174	18.118	40.774
3	1.387	11.562	59.459	1.387	11.562	59.459	1.750	14.581	55.355
4	1.124	9.364	68.823	1.124	9.364	68.823	1.616	13.468	**68.823**
5	0.939	7.828	76.651						

Table 25 Principal component analysis of variables in category B

	Component [a]			
	1	2	3	4
[B01M_A] My organization has marketing knowledge.	**0.849**	-0.120	0.179	-0.029
[B01M_B] My organization has sales skills.	**0.812**	0.320	0.129	-0.107
[B01M_C] My organization has managerial skills to handle tasks effectively.	0.325	**0.634**	0.105	0.053
[B01M_D] My organization has forecasting capabilities about the future market.	0.064	**0.714**	0.330	-0.361
[B01M_E] The business model (i.e. how you earn revenue) of our PET product/service is profitable.	0.512	**0.478**	0.101	-0.370
[B01M_F] My organization has easy access to investment capital, including R&D investment.	0.038	0.090	**0.823**	-0.215
[B01M_G] Our PET product/service needs monetary public support to develop and thrive.	-0.266	0.161	0.121	**0.773**
[B01M_H] Getting funding is a very bureaucratic process (e.g. procedures to get grants/subsidies).	0.080	-0.069	-0.221	**0.754**
[B01M_I] Finding risk-taking funders for our PET product/service is easy.	0.195	0.055	**0.857**	0.083
[B01M_J] Competition in our market is intense.	0.550	0.306	0.253	-0.171
[BD19M_A] Under what license is your PET product/service created? -	**-0.727**	-0.307	0.140	-0.058
[BE01M_F] My organization has experienced growth in uptake (i.e. understanding, mental grasp) of the PET product/service in the last year.	0.138	**0.829**	-0.111	0.289

a. yellow 0.4 < r < 0.6; green: 0.6 < r < 0.8; blue: r > 0.8;

The variables used to define the extracted factors are highlighted in bold in Table 25:

Factor 1: Good sales performance

Factor 2: Good absorptive capacity

Factor 3: Ability to attract funding

Factor 4: Ease of getting public monetary support when needed

6.5.3.2   Category C

The three factors explain 62.683% of the variance (see Table 26). The KMO Bartlett's test is .649.

Table 26 Cumulative variance explained by factors by category C

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	3.093	30.925	30.925	3.093	30.925	30.925	2.466	24.662	24.662
2	1.823	18.233	49.158	1.823	18.233	49.158	1.905	19.049	43.711
3	1.353	13.525	62.683	1.353	13.525	62.683	1.897	18.972	**62.683**
4	0.953	9.528	72.212						

Table 27 Principal component analysis of variables in category C

	Component [a]		
	1	2	3
[C01M_A] My organization has easy access to technical knowledge needed for the development of PETs (e.g from a university or research centre).	-0.032	0.036	**0.736**
[C01M_B] My organization is part of an environment where it is easy to talk with anyone we need to, regardless of rank or position.	-0.303	0.069	**0.742**
[C01M_C] My organization cooperates with other PET producing firms.	0.227	0.104	**0.618**
[C01M_D] My organization cooperates with policy makers that support the development of PETs.	0.325	**0.772**	0.337
[C01M_E] My organization participates in a regional community to promote privacy engineering.	0.036	**0.881**	-0.010
[C01M_F] Data protection authorities guidance plays an important role in our PET design.	**0.868**	0.002	-0.010
[C01M_G] Standards (from standardisation bodies) play an important role in our PET design.	**0.771**	0.243	0.120
[C01M_H] The law is an important source of guidance in our PET design.	**0.806**	0.350	-0.020
[CD01M_E] Our PET product/service makes good use of existing IT systems (e.g. public key servers, remote servers and clouds).	0.318	0.460	-0.068
[CD01M_P] My organization uses PETs that are designed by other organizations.	-0.340	0.351	-0.539

a. yellow $0.4 < r < 0.6$; green: $0.6 < r < 0.8$; blue: $r > 0.8$;

The variables used to define the extracted factors are highlighted in bold in Table 27:

Factor 1: External guidance (legislative, data protection authorities, standardization)

Factor 2: Promotion and support of PET development efforts

Factor 3: Inter-organizational connectedness (ability to exchange knowledge and collaborate)

To test the decision to change variables among categories, EC01M_J *3rd party reliance* and EC01M_K *requirement of component or infrastructure not available yet* have been introduced in category C again. However, the results yielded less distinctive factor loadings than the loadings before introducing these two variables again. Also, variable EC01M_I *labour laws* decreased factor loadings and thus the distinctive character of variables in the factors. The earlier action to swap these variables to a new category have thus been favourable.

6.5.3.3   Category D

The three factors explain 67.198% of the variance (see Table 28). The KMO Bartlett's test is .386.

Table 28 Principal component analysis of variables in category D

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	2.660	18.997	18.997	2.660	18.997	18.997	2.122	15.158	15.158
2	2.022	14.440	33.438	2.022	14.440	33.438	2.076	14.830	29.988
3	1.954	13.957	47.395	1.954	13.957	47.395	1.968	14.061	44.049
4	1.524	10.883	58.278	1.524	10.883	58.278	1.759	12.564	56.613
5	1.249	8.920	67.198	1.249	8.920	67.198	1.482	10.585	**67.198**
6	0.999	7.139	74.337						

Table 29 Cumulative variance explained by factors by category D

	Component [a]				
	1	2	3	4	5
[D01M_A] Customers are satisfied with our PET product/service.	**0.871**	0.196	-0.167	0.075	-0.016
[D01M_B] Customers find our PET product/service easy to use.	**0.695**	-0.111	0.152	-0.004	0.025
[D01M_C] Users are able to properly try out our PET product/service, before deciding whether to use it.	0.038	-0.122	0.212	**0.814**	-0.060
[D01M_D] Our PET product/service gives users more control over their personal data processing.	0.050	**0.583**	0.271	0.243	**0.516**
[D01M_F] We offer open access to the inner-workings of our PET product/service (e.g. open source, database access, public auditing).	-0.033	0.113	-0.653	0.187	-0.228
[D01M_G] Privacy is sometimes an afterthought in our PET product/service design.	-0.315	**-0.733**	-0.165	0.147	-0.149
[D01M_H] Our PET product/service ensures increased privacy with big data.	0.025	0.009	0.096	-0.179	**0.843**
[D01M_L] Laws that don't respect privacy incentivizes our organization to create PET products/services.	-0.046	**0.756**	-0.023	0.454	-0.035
[D01M_M] Users are required to use our PET product/service by their superior (e.g. a boss) or by law.	0.509	-0.084	0.287	-0.300	-0.479
[D01M_N] Our PET product/service has automated privacy policy enforcement.	-0.034	0.199	**0.722**	0.089	-0.331
[D01M_O] Our PET product/service does decentralised data analytics.	-0.065	0.031	**0.654**	0.077	0.096
[D01M_Q] PET interoperability with other PETs is important.	0.119	0.305	-0.342	**0.711**	-0.058
[D01M_R] Our PET product/service has high interoperability with other PETs.	**0.703**	0.198	-0.190	0.111	0.019
[DE08M_A] My organization asks itself why it innovates the PET product/service (compared to what and how to innovate). -	0.005	**-0.608**	0.387	0.340	0.268

a. yellow 0.4 < r < 0.6; green: 0.6 < r < 0.8; blue: r > 0.8;

The variables used to define the extracted factors are highlighted in bold in Table 29:

Factor 1: User centred design, Interoperability satisfaction among PETs

Factor 2: Having strict privacy core values

Factor 3: Decentralized policy automation

Factor 4: User's ability to try out interoperability

Factor 5: (Big) data privacy control

6.5.3.4 Category E

The three factors explain 73.672% of the variance (see Table 30). The KMO Bartlett's test is .549.

Table 30 Cumulative variance explained by factors by category E

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	2.474	20.613	20.613	2.474	20.613	20.613	2.120	17.670	17.670
2	2.338	19.483	40.096	2.338	19.483	40.096	2.106	17.549	35.219
3	1.839	15.328	55.424	1.839	15.328	55.424	1.775	14.794	50.013
4	1.176	9.800	65.225	1.176	9.800	65.225	1.628	13.565	63.579
5	1.014	8.448	73.672	1.014	8.448	73.672	1.211	10.094	**73.672**
6	0.782	6.520	80.193						

Table 31 Principal component analysis of variables in category E

	Component [a]				
	1	2	3	4	5
[E01M_A] My organization uses an on-line platform to create and share PETs.	-0.019	**0.622**	-0.228	0.350	0.375
[E01M_B] We use feedback of our users to update the development roadmap.	-0.039	**0.768**	0.083	-0.341	0.000
[E01M_C] Fixing critical errors and bugs is of highest importance to our PET product/service.	0.009	**0.850**	0.050	0.005	-0.161
[E01M_D] My organization defines goals at the start of each project.	-0.024	-0.005	**0.876**	-0.011	0.068
[E01M_E] My team is geographically centralized (e.g. working close to each other).	-0.323	**-0.471**	**0.486**	-0.054	0.386
[E01M_F2] We can easily find employees with technical skills (e.g. computer science and engineering) that are suitable for our organization.	**0.926**	0.028	-0.093	0.001	-0.035
[E01M_F3] We can easily find employees with non-technical skills (e.g. economics, law, psychology and ethics) that are suitable for our organization.	**0.445**	0.358	**0.546**	-0.154	0.108
[E01M_F4] We can easily find employees with multidisciplinary skills (i.e both technical and non-technical skills) that are suitable for our organization.	**0.902**	-0.070	0.081	-0.043	0.173
[E07M_A] How formalized is your software management process? -	0.009	-0.074	**0.498**	**-0.510**	-0.323
[EC01M_I] Our organization experiences too strict employment and labour laws (i.e. protecting employees) that have a negative effect on our innovative abilities.	0.155	-0.062	0.092	-0.135	**0.827**
[EC01M_J] We heavily rely on 3rd party technology (e.g. open source).	0.228	0.028	-0.337	**0.663**	-0.229
[EC01M_K] We require a component or infrastructure that is not available yet.	-0.262	-0.202	0.164	**0.802**	-0.089

a. yellow $0.4 < r < 0.6$; green: $0.6 < r < 0.8$; blue: $r > 0.8$;

The variables used to define the extracted factors are highlighted in bold in Table 31:

Factor 1: Ease of finding the right employees

Factor 2: Decentralized agility of the organization

Factor 3: Formalized and standardised management (i.e. mechanistic organization)

Factor 4: Reliance on (not yet available) 3rd party technology & infrastructure

Factor 5: Strictness of labour laws

6.6 Linear regression model

Multiple linear regression analysis is executed with a stepwise approach. The findings for both *consumer demand* and *business demand* are shown in the next two sections.

6.6.1 Consumer demand

The stepwise linear regression for consumer demand produces 3 models. With df1 1 and df2 13, the critical value of F is 4.67. Table 34 shows that the F statistics is 18.351 which is greater that the necessary 4.67. Also, the significance shows .000 which is smaller than .05, i.e. a measure whether the model is

statistically significant. *Sig. F change* in Table 32 shows the significance for each iteration. A significant F-change means that the variables added in that step significantly improved the prediction.

Table 32 Model summary of consumer demand

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	,645[a]	0.417	0.378	0.85603175	0.417	10.712	1	15	0.005
2	,730[b]	0.534	0.467	0.79233526	0.117	3.509	1	14	0.082
3	,826[c]	0.683	0.610	0.67788045	0.149	6.127	1	13	0.028

Table 33 ANOVA of model 3 for consumer demand

Model		Sum of Squares	df	Mean Square	F	Sig.
7	Regression	18.117	7	2.588	18.351	,000[h]
	Residual	1.269	9	0.141		
	Total	19.387	16			

In Table 34 the tolerance values are higher than the minimum threshold of 0.2. Higher thresholds are better because this keeps the Variance Inflation factor (VIF) low. High VIF's may point towards high (multi) collinearity. The standardized Beta coefficient of factor P3_3 is not statistically significant (0.423 > 0.05). However, the standardized Beta coefficient shows a weak driver ($\beta = 0.176$) that is interesting to explore nevertheless. Strictly it should not be included in the model.

Table 34 Coefficients of consumer demand

Model		Unstandardized Coefficients		Standardized Coefficients			Confidence Interval for B		Collinearity Statistics	
		B	Std. Error	Beta	t	Sig.	Lower Bound	Upper Bound	Tolerance	VIF
1	(Constant)	0.231	0.208		1.107	0.286	-0.213	0.675		
	P3_3 Cat C: Inter-organizational connectedness (ability to exchange knowledge and collaborate)	0.568	0.173	0.645	3.273	0.005	0.198	0.938	1.000	1.000
2	(Constant)	0.250	0.193		1.292	0.217	-0.165	0.664		
	P3_3 Cat C: Inter-organizational connectedness (ability to exchange knowledge and collaborate)	0.419	0.179	0.476	2.337	0.035	0.034	0.803	0.803	1.246
	P4_2 Cat D: Having strict privacy core values	0.450	0.240	0.382	1.873	0.082	-0.065	0.965	0.803	1.246
3	(Constant)	0.364	0.172		2.120	0.054	-0.007	0.735		
	P3_3 Cat C: Inter-organizational connectedness (ability to exchange knowledge and collaborate)	0.155	0.187	0.176	0.827	0.423	-0.249	0.558	0.541	1.849
	P4_2 Cat D: Having strict privacy core values	0.711	0.231	0.604	3.079	0.009	0.212	1.211	0.635	1.575
	P5_4 Cat E: Reliance on 3rd party technology & infrastructure	-0.503	0.203	-0.479	-2.475	0.028	-0.943	-0.064	0.651	1.537

In Figure 17, model 3 shows normality (normal bell shape) in the histogram. Also, the normal P-P plot shows that the expected cumulative probability follows the linear line. Furthermore, the scatterplot shows that there is no pattern of the residuals (e.g. a upward sloping pattern) which means there is no heteroscedasticity in the residuals.
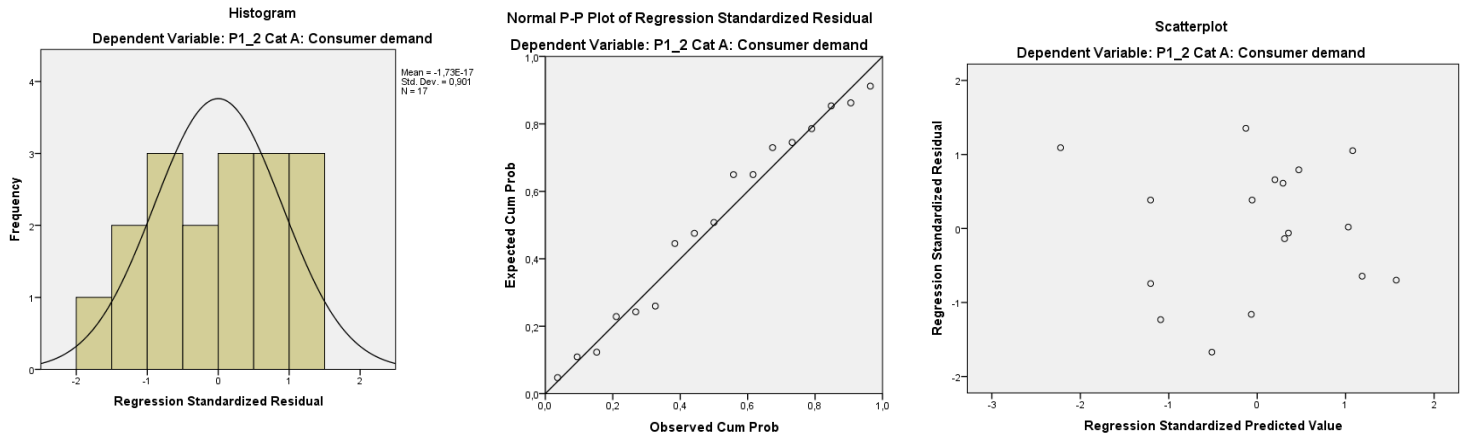
Figure 17 Validity plots for consumer demand

The model for consumer demand is as follows:

$$D_C = 0.604 P_2 - 0.479 P_3$$

Where:

D_C = Demand by consumers for PETs

P_2 = Having strict privacy core values

P_3 = Reliance on (not yet available) 3rd party technology & infrastructure

Removed factor because of statistical insignificance (0.424 > 0.05):

P_1 = Inter-organizational connectedness (ability to exchange knowledge and collaborate)

It seems that P_1 and P_2 are drivers and P_3 is a barrier to the adoption and diffusion of consumer PETs. It seems that strict privacy core values is deemed the most important driver for consumer PETs. The reliance on (not yet available) 3rd party technology & infrastructure is the strongest (and only) statistically significant barrier found. Inter-organizational connectedness is a driver to PET adoption & diffusion, although of a weaker strength.

6.6.2   Business demand

The stepwise linear regression for business demand produces 11 models. Table 35 shows that the last model that significantly changed F was model 7. With df1 1 and df2 9, the critical value of F is 5.12. Table 36 shows that the F value is 18.351 which is larger than 5.12.

Table 35 Model Summary of business demand

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics					Durbin-Watson
					R Square Change	F Change	df1	df2	Sig. F Change	
1	,654[a]	0.427	0.389	0.86034600	0.427	11.191	1	15	0.004	
2	,747[b]	0.557	0.494	0.78282559	0.130	4.118	1	14	0.062	
3	,823[c]	0.678	0.604	0.69290479	0.121	4.869	1	13	0.046	
4	,894[d]	0.799	0.732	0.57038036	0.121	7.185	1	12	0.020	
5	,912[e]	0.832	0.755	0.54457182	0.033	2.164	1	11	0.169	
6	,941[f]	0.886	0.818	0.47007681	0.054	4.763	1	10	0.054	
7	,967[g]	0.935	0.884	0.37555361	0.049	6.667	1	9	0.030	
8	,967[h]	0.934	0.895	0.35650858	0.000	0.011	1	9	0.917	
9	,977[i]	0.955	0.920	0.31064029	0.021	4.171	1	9	0.071	
10	,983[j]	0.966	0.932	0.28682276	0.011	2.557	1	8	0.148	
11	,988[k]	0.976	0.945	0.25781706	0.010	2.901	1	7	0.132	2.354

Table 36 ANOVA of model 7 for business demand

Model		Sum of Squares	df	Mean Square	F	Sig.
7	Regression	18.117	7	2.588	18.351	,000[h]
	Residual	1.269	9	0.141		
	Total	19.387	16			

In Table 37 the tolerance values are higher than the minimum threshold of 0.2. Higher thresholds are better because this keeps the Variance Inflation factor (VIF) low. High VIF's may point towards high (multi) collinearity. The standardized Beta coefficient of factor P4_1 is tiny (β = 0.013) and is not statistically significant (0.917 > 0.05); therefore it will not be included in the model.

Table 37 Coefficients of business demand

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95,0% Confidence Interval for B		Collinearity Statistics	
		B	Std. Error	Beta			Lower Bound	Upper Bound	Tolerance	VIF
7	(Constant)	-0.216	0.107		-2.011	0.075	-0.459	0.027		
	P3_2 Cat C: Promotion and support of PET development efforts	0.712	0.121	0.582	5.872	0.000	0.438	0.986	0.739	1.353
	P4_1 Cat D: User centred design, Interoperability satisfaction among PETs	0.015	0.142	0.013	0.107	0.917	-0.307	0.337	0.480	2.082
	P5_2 Cat E: Decentralized agility of the organization	0.381	0.115	0.329	3.323	0.009	0.122	0.640	0.743	1.346
	P4_4 Cat D: User's ability to try out interoperability	-0.524	0.100	-0.509	-5.262	0.001	-0.749	-0.299	0.779	1.284
	P3_3 Cat C: Inter-organizational connectedness (ability to exchange knowledge and collaborate)	0.392	0.106	0.439	3.695	0.005	0.152	0.632	0.515	1.942
	P5_5 Cat E: Strictness of labour laws	0.474	0.137	0.378	3.451	0.007	0.163	0.784	0.607	1.648
	P3_1 Cat C: External guidance (legislative, data protection authorities, standardization)	0.320	0.124	0.305	2.582	0.030	0.040	0.601	0.522	1.914

In Figure 18, model 7 shows normality (normal bell shape; with a little gap in the middle) in the histogram. Also, the normal P-P plot shows that the expected cumulative probability follows the linear line. Furthermore, the scatterplot shows that there is no pattern of the residuals (e.g. a upward sloping pattern) which means there is no heteroscedasticity in the residuals.
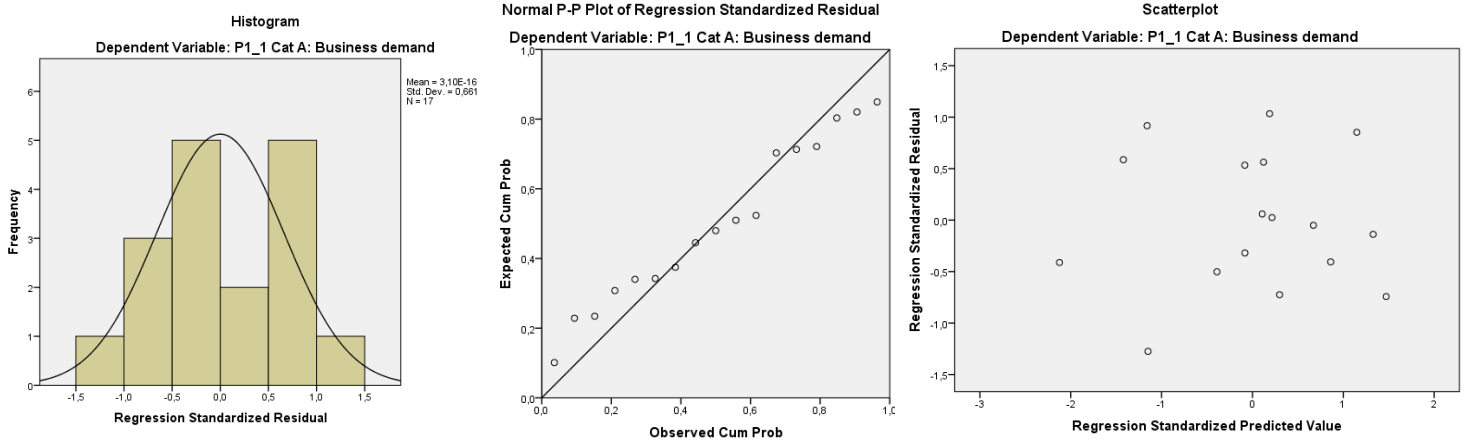

Figure 18 Validity plots for business demand

The model for business demand is as follows:

$$D_B = 0.582P_1 + 0.329P_3 - 0.509P_4 + 0.439P_5 + 0.378P_6 + 0.305P_7$$

Where:

D_B = Demand by businesses for PETs

P_1 = Promotion and support of PET development efforts

P_3 = Decentralized agility of the organization

P_4 = User's ability to tryout interoperability

P_5 = Inter-organizational connectedness (ability to exchange knowledge and collaborate)

P_6 = Strictness of labour laws

P_7 = External guidance (legislative, data protection authorities, standardization)

Removed factor because of statistical insignificance ($0.075 > 0.05$):

P_2 = User centric design, Interoperability satisfaction among PETs

It seems that all factors are drivers except for P_4. The strongest driver to business PET adoption & diffusion is the promotion and support of PET development. Also quite a strong driver is the inter-organizational connectedness. A strong barrier is the user's ability to tryout interoperability. Moderately strong drivers are user centric design, strictness of labour laws and external guidance. User centric design is a driver but almost non-existent in this model.

6.6.3 Hypotheses testing

Sub chapter 6.6 has opened the possibility to test the hypotheses. During the data analysis two types of adoption and diffusion have been discovered. One for consumer demand and one for business (and public organizations) demand.

Concerning all hypotheses outcomes: please find sub chapter "6.8 Discussion and conclusion" to read the discussion and implications of these outcomes.

Hypothesis 1 will be tested both consumer and business demand. Hypothesis 1 seems to be true for business demand only (see Table 34 and Table 37 for statistics).

> **Hypothesis 1 testing:** "Inter-organizational collaboration is a driver to PET adoption & diffusion."
> Since factor P3_3 has significance $p = .423$ and the standardized Beta is positive ($\beta = .176$) the hypothesis is **rejected** ($p > .05$) for consumer demand of PETs.

> **Hypothesis 1 testing:** "Inter-organizational collaboration is a driver to PET adoption & diffusion."
> Since factor P3_3 has significance $p = .005$ and the standardized Beta is positive ($\beta = .439$) the hypothesis is **accepted** ($p < .05$) for business demand of PETs.

Hypothesis 2 will only be tested for business demand (see Table 37 for statistics).

> **Hypothesis 2 testing:** "The promotion and support of PET development by policy makers is a driver to adoption & diffusion of PETs."
> Since factor P3_2 has significance $p = .000$ and the standardized Beta is positive ($\beta = .582$) the hypothesis is **accepted** ($p < .05$) for business demand of PETs.

Hypothesis 3 will only be tested for business demand (see Table 37 for statistics).

> **Hypothesis 3 testing:** "External guidance by standardization bodies, legislators and/or data protection authorities would be a driver to PET adoption & diffusion."
> Since factor P3_1 has significance $p = .030$ and the standardized Beta is positive ($\beta = .305$) the hypothesis is **accepted** ($p < .05$) for business demand of PETs.

Hypothesis 5 will only be tested for business demand (see Table 37 for statistics).

> **Hypothesis 5 testing:** "Interoperability between PETs will drive PET adoption and diffusion."
> Since factor P4_4 has significance $p = .001$ and has a negative standardized Beta ($\beta = -.509$) the hypothesis is **rejected** ($p < .05$) for business demand of PETs.

Hypothesis 6 will only be tested for business demand. (see Table 37 for statistics)

> **Hypothesis 6 testing:** "Agility in an organization is a driver for PET adoption & diffusion."
>
> Since factor P5_2 has significance p = .005 and has a positive standardized Beta (β = .329) the hypothesis is **accepted** (p < .05) for business demand of PETs.

Hypothesis 7 will only be tested for overall demand.

> **Hypothesis 7 testing:** "An organization with marketing skills, sales skills and/or a good absorptive capacity should drive adoption & diffusion of PETs."
>
> No factors are generated that can either confirm or reject this hypothesis. However, the correlation matrix in "Appendix G: Correlation matrix r > 0.45" shows strong correlations between marketing skills, managerial skills and multidisciplinary skills. Also the process of obtaining funding seems to be easier which asserts the effectiveness of applying knowledge in the PET development domain.
>
> This hypothesis can be **accepted** with the notice that correlation does not imply causation.

Like stated before: concerning all hypotheses outcomes, please find sub chapter "6.8 Discussion and conclusion" to read the discussion and implications of these outcomes.

6.7 Open-ended questions

The open-ended questions included in each category add additional context and even recommendations from respondents. For each category (from A to E) the most striking issues are added below.

Category A (adoption and diffusion) asked respondents which other important factors stimulate the adoption and diffusion of PETs, according to the respondent. Category A received responses from 37 respondents.

The primary driver, stated by over a dozen respondents, is considered to be the news. Especially news items concerning hacks, censorship, the Snowden leaks and hacked competitors have been mentioned. These events seem to give users an incentive to explore and compare PETs to users. This issue has not been part of the questionnaire and could be an interesting issue for future research. Other issues considered to drive adoption and diffusion are supporting foundations like Electronic Frontier Foundation (EFF), legislative support, independent audits, good user interface design, compatibility and awareness. A noteworthy mention is that PETs should not be obstructive to users: they should be effective but invisible to users.

While the news (of the media on general) is an important variable on the sudden interest of PETs, the attention span of people remains problematic. The variables chosen in this research have been mainly chosen for their structural (i.e. prolonged) effects on the adoption and diffusion of PETs. It is true that news can have a lasting effect on behaviour and views of people. However, it is the perceived sense of

urgency that leads to lasting behavioural change. Nevertheless, the creation of awareness is the first step to behavioural change, i.e. using PETs. It would be interesting to see what structural effect the media in general (e.g. news on TV, news on-line and social media) has on the adoption & diffusion of PETs.

Category B (Business viability & sustainability) asked respondents which other important factors concerning the business viability & sustainability of PET development/deployment. Category B received responses from 22 respondents.

The primary issues revolve around finance. Interestingly, the statement (made in section 6.2.11) about the possible difficulties of acquiring subsidies, grants and the like from the European Union is emphasized in the open-ended questions. The main difficulty seems to be of a bureaucratic nature which is perceived as a tedious process and therefore not pursued. Also the difficulties of simultaneously working on PET development and writing grants to financially support such activities is highlighted. Furthermore, the difficulty of attracting venture capital is emphasized. All respondents that stated their concerns work in organizations of 1 to 9 people. It could be that attracting funds from subsidies and grants is especially difficult for smaller organizations.

In contrast to the difficulties of acquiring monetary public support, one respondent in category B has stated that their development is entirely supported by grants. This organization is 20 to 49 employees in size. It could be that more diverse expertise is present in this larger organization that includes legal knowledge that may smooth applications to subsidies and grants. Indeed, "Appendix G: Correlation matrix r > 0.45' shows that moderate to strong correlations exist between the law being considered an important source of guidance (variable C01M_M) on the one hand, and the extent to how formalised an organization is (variable E07M_A) on the other hand. The affinity with formal processes such as applying for grants and subsidies may therefore be easier for such organizations. Moreover, organizations that find the law an important source of guidance also have stronger marketing knowledge, sales skills and cooperate with policy makers to support the development of PETs. Again, these are competences that do not contribute to PET development directly but may serve the sustainability of PET development.

Not all respondents feel that finance is an issue. Some respondents have stated that they deliberately do not pursue the acquisition of financial means. Reasons mentioned are staying independent and that teams consist solely of volunteers or community members spending their free time. The latter is an interesting case, because financial means are attracted from a primary source outside the PET project (i.e. a day job) making PET development a secondary (i.e. spare time) activity.

In general, the main issue of business viability & sustainability seems to be the difficulty to attract funding (when needed) because of bureaucratic processes that are currently needed to acquire the funding. This issue was first discussed in section 6.2.11 and now affirmed by the open-ended questions. Especially the European Union, which has stated in recent years and months that cyber security and

privacy are high on the agenda, should find a way to ease such bureaucratic burden. The effect would be that entrepreneurs can focus on their PET product or service, rather than spend a substantial amount on paper work.

Category C (Knowledge & innovation environment) asked respondents which other important environmental (e.g. market) factors stimulate PETs. Category C received responses from 21 respondents.

Respondents reacted with a diverse range of issues. The three issues considered to have the biggest impact are: competition for engineering talent, the weak position of privacy engineering of the EU, and supply chain issues. Indeed, these issues have a direct effect on the production power (Bruijn & Heuvelhof, 2008, pp. 37–38) of organizations.

First, one respondent stated that Silicon Valley (San Francisco, USA) is considered to be an environment with intense competition for engineering talent and should be included in Category C. As has turned out in section 6.6.2 , strict labour laws are a driver to the business demand of Privacy-Enhancing Technologies. Thus, the concern of intense competition for engineering talent is justified. Indeed, when labour laws would not offer enough protection to employees they would be more focused on staying employed than focussing on PET innovation.

Second, the privacy innovation position of the European Union is considered to be weak by one respondent. The United States, Russia, China and Isreal would be ahead of the European Union. Concerning building security tools and solutions. EU organizations are currently thus opting for foreign solutions, rather than EU produces PETs. However, if EU organizations would choose EU based products and services, more engineers would be needed in the EU to build such solutions. In turn, more skilled engineers will also be attracted from abroad, boosting the privacy innovation position of the EU and thus its production power. These findings are confirmed to be true based on a survey completed in 2016 among 19,641 IT professionals worldwide (Broersma, 2017). The current cyber security professional shortage is expected to rise to a shortage of 350,000 by 2022. Furthermore, 48% of the respondents in that research confirm that the skills shortage was due to a lack of qualified talent. An interesting topic for future research would be to find out how the lack of cyber security professionals affects the adoption and diffusion of PETs.

Third, supply chain issues may impede the production of PETs. For example, when developing and testing PETs it is difficult to acquire the needed hardware components for competitive prices when ordered in small quantities (i.e. less than 1,000). Such restrictions have an effect especially when developments are in an early stage when demand still has to accelerate. One solution to this could be to create a European platform for collective ordering of components from e.g. China. The European Union would be able to provide such a platform to bring organizations that develop PETs together.

Other issues brought forward are the need for proper security education and a digital infrastructure that is reliable. Currently universities in the Netherlands like Delft University of Technology, Eindhoven University, Twente University and Wageningen University offer one integrated cyber security education that synergistically integrates the best that each university has to offer (4TU Federation, 2017).

Lastly, the lack of independent PET certification and standards specifically for PETs is seen as a barrier to the adoption and diffusion of PETs. Such certification and standards are excellent tasks for specialized authorities and the European Union government.

Category D (Design values) asked respondents which other important values to consider in the design, development and deployment of PET products/services. Category D received responses from 17 respondents. The total number of words spent on the open-ended question in this category was around 40% more than in other categories which makes Design values the most debated category.

Values to consider that have been express the most relate to transparency, auditing, open source and data minimization. Also the balance between design, usability and security has been discussed. However, these issues have been considered to be captured within the closed-ended questions of the questionnaire.

Debated issues that add to the closed-ended questions are the concern that some organizations offer PETs while instead they offer anti-PETs. An example mentioned by respondents is AdBlocker which allows advertisers to whitelist their advertisement upon paying AdBlocker a fee (Griffin, 2015). While AdBlocker does block the majority of ads most users (the author of this thesis included) are unaware of such practises and could allow advertisers to track users through cookies or when clicking the advertisement link. Such practises would be privacy invasive. The issue of certification of PETs by an authority (as mentioned under category C) would be able to make user aware of the degree of privacy a PET is able to offer. When users find out themselves that a PET does not do that it is advertised or intended to so (e.g. blocking ads) users' trust may diminish which would impede PET adoption and diffusion.

Another issue that would drive the adoption and diffusion of PETs is to consider the contextual nature and culture of privacy. This exact issue has been discussed in the problem statement (sub chapter 2.1) and in theory and concepts (sub chapter 3.1). PET developers should also have discussions with their users so users know the culture of the organization that develops the PET. Indeed, the attitude of an organization towards its users can explicitly be interpreted by users if the organization communicates their core values in practise. Likewise, the interaction is an important indicator of what values are captured in a PET product or service.

Two responses valuable to report remain in this category. First, the difficulty of balancing data minimization and user statistics on the one hand, and branding on the other hand.

First, there exists a tension between balancing data minimization and the need for user statistics. While such statistics may reveal the successes and problems of a PET product or service, they also defy the purpose of using the PET, namely privacy. One of the respondents stated that using web crawlers solved some of his/her problems. At the same time, acquiring intel about users is easiest by just asking them. This will kill two bird with one stone, because besides learning about user desires they will most likely appreciate the direct attention.

Second, and finally, the usability of a PET is stresses by multiple respondents. Usability can be diminished severely when the development of a PET is not finished yet. However, the interviews showed that the drive for perfection can lead to the demise of a PET. Indeed, a balance is needed where a 'good enough' increment leads to feedback on which a new increment of a PET product/service can be created. When this process is well established the branding of the PET is considered important too because it involves building a community and searching for engagement with the PET. This in turn leads to a movement that supports the PET.

Category E (Research & development) asked respondents which other important factors do you know for the research & development of PETs. Category D received responses from 9 respondents.

Two drivers mentioned most often are having proper documentation when developing PETs and acquiring new knowledge by reading papers and blogs. Good documentation is important in particular when an organization has a high churn rate. However, in the long-term the natural flow of staff leave the organization necessitates the need for documentation on design choices, conventions and how the internals of a PET work. Especially a lack of understanding with future generations of developers may potentially increase the number of bugs and security vulnerabilities. Good documentation at least give codified support to future developers on the PET.

Finally, the dynamics within development team have also be mentioned in the open-ended questions of Category E. Important factors are considered to be good leadership and proper feedback mechanisms. Indeed, leadership has been considered as a separate category in this thesis (see "Appendix A: Constructs based on technology management literature"). However, this would be complicated the model. Nevertheless, proper leadership and feedback mechanisms such as code reviewing and keeping a productive friction free group dynamic will have its influence on the quality of the PET product/service itself.

6.8 Discussion and conclusion

The drivers and barriers of Privacy-Enhancing Technologies adoption and diffusion can be distinctively split in the consumer demand and business demand.

For consumer demand the strongest driver is *strict privacy core values* (β = .604) followed by *Inter-organizational connectedness* (β = .176). A strong barrier is the *reliance on (not yet available) 3rd party technology & infrastructure* (β = -.479). Again, *Inter-organizational connectedness* is not statistically significant but is included merely to explorer the factor.

For consumer demand it seems that *strict privacy core values* (β = .604) is deemed the most important driver for consumer PETs. This means that consumers find the uncompromised quality of privacy the most important feature of PETs. Especially contextual privacy is a term that applies to natural persons as explained in for individuals the concept of contextual privacy is important. As explained in section 3.1.4 individuals like the free and unconstraint flow of information if that enables freedom of speech, the pursuit of wealth, efficiency and security. In contrast, individuals dislike it when information-based harm occurs, when relations to other individuals are severed and (at least in the democratic world) when freedom and autonomy is taken away. Indeed, it comes as no surprise that individuals use PETs to protect their privacy and that the privacy feature is of utmost importance. Therefore, strict privacy core values drive consumer demand.

The *reliance on (not yet available) 3rd party technology & infrastructure* (β = -.479) is the strongest (and only) statistically significant barrier found. Especially infrastructure that is not available yet has naturally a detrimental effect on progress of PET development. Organizations have the possibility to develop such infrastructure themselves, collaborate and utilize the expertise of other organizations or wait for technological advance to happen in the future. Organizations often do not have the resources to develop and manage an entire system (J. Roland Ortt & Smits, 2006) thus collaboration should be preferred. Also, the pre-diffusion phase of a new technology can be shortened dramatically if somehow existing infrastructure is used (J. Roland Ortt, 2010).

Inter-organizational connectedness (β = .176) is a (statistically non-significant) driver to consumer PET adoption & diffusion, although of a weaker strength. It is still discussed here for exploratory reasons. It is a factor that reflects the ability to exchange knowledge and collaborate. More specifically, easy access to technical knowledge, an environment where it is easy to talk about PET development when needed, and cooperation with other PET producing firms. It comes as no surprise that inter-organizational connectedness is a driver. However, such connectedness is noticed by consumers and must be noticeable in the perceived quality of the produced PET by consumers.

For business demand it seems that the strongest driver is the *promotion and support of PET development* (β = .582). Also quite a strong driver is the *inter-organizational connectedness* (β = .439).

Moderately strong drivers are *strictness of labour laws* (β = .378) and *external guidance* (β = .305). *User centric design* (β = .013) is a driver but almost non-existent in the business demand model. A strong barrier is the *user's ability to try out interoperability* (β = -.509).

For business demand the strongest driver is the *promotion and support of PET development* (β = .582). This means that an organization cooperates with policy makers that support PET development and that the organization participates in a regional community to promote privacy engineering. It seems that promoting PETs through policies and communities does indeed pay off. Such activities turn out to be the most influential driver for business demand. The reason for this could be that PET developers could be seen as policy entrepreneurs that have a solution but need someone's problem to solve (Kingdon, 1995, pp. 165–190). Businesses have (latent) problems and could be more willing to adopt a PET when the PET turns out to solve a problem a business has. Regardless, promotion and support of PETs is a strong driver.

Also quite a strong driver is the *inter-organizational connectedness* (β = .439). In contrast to consumer demand, this coefficient is statistically significant for businesses and (because business and public organizations correlate highly) also to public organizations. Businesses demand rises when an organization is able to cooperate with others and has access to technical knowledge (e.g. via universities and tech centres).

Moderately strong drivers are *strictness of labour laws* (β = .378). At first glance, this outcome was baffling because during interviews with Dr. Phil Zimmermann strict labour laws would impede grand achievements like the Google's and Facebook's. All such enormous organizations originate from the United States where labour laws are a lot less restrictive compared to the European Union. Indeed, an organization is able to quickly attract new talent and discarding staff that underperforms. However, the open-ended feedback received in category C (sub chapter 0) emphasizes concerns with this rationale. Notably, when labour laws would not offer enough protection to employees they would be more focused on staying employed than focussing on PET innovation. Because the focus shifts from the latent fear of unemployment to having job security organizations may attract talent that may otherwise seek a job position elsewhere.

Another moderately strong driver is *external guidance* (β = .305). This guidance originates from data protection authorities, standardization and legislative organizations. This driver can be analysed from three different perspectives. First, as described in the scientific problem, neither first movers (Schilling, 2012, p. 94) nor pioneers (J. Roland Ortt, Zegveld, & Shah, 2007b) are guaranteed market dominance with their PET. Innovation involves the great risk of making a large investment while a PET developer entering the market at a later time profits from the experience of innovators and first-movers and wins the battle for market dominance. Consequently, external guidance could be a driver because this alleviates organisations from the risk of making the wrong design choices or betting on a wrong future

market. Second, as has been stated in sub chapter 0organizations that find the law an important source of guidance also have stronger marketing knowledge, sales skills and cooperate with policy makers to support the development of PETs. Such competences may not contribute to PET development directly but may serve the sustainability of PET development indirectly. Indeed, this non-technical knowledge may lead to the affinity with formal processes such as applying for grants and subsidies. Third, guidance organizations may have the ability to bring PET developing organizations together and even introduce weak ties (Granovetter, 1973) that may benefit PET development with novel perspectives and approaches.

A driver that is almost non-existent in the business demand model and not statistically significant to boot is *User centric design* (β = .013). For exploratory reasons it is still discussed here. As discussed in sub chapter 0, interface design from the perspective of the user allows for intuitive usage for the user. This can be explained in two ways. First, a good example is the introduction of the iPhone: no phone existed with the features that the iPhone combined into one product but users immediately understood the potential the device had. Second, without a manual an iPhone can even be successfully operated by a toddler due to its intuitive design. In contrast, Spartan designs may work for tech savvy users but for the adoption & diffusion of a PET to a broader public the usability and intuitive usage of a PET must be taken into consideration.

Besides drivers for business demand, also one significant barrier exist. This strong barrier is the *user's ability to try out interoperability* (β = -.509). The factor consists of the ability of users to try out a PET product/service before deciding whether to us it on the one hand, and whether interoperability with other PETs is important on the other hand. At first glance, this barrier seems counterintuitive. However, two issue come to mind. First, legal issue may arise that prevent interoperability such as licensing and other legal (e.g. contractual) conflicts (Munavijayalakshmi & Kumar, 2017). Second, there may simply be no business case for interoperability (Davis, 2017) because expenses for integration and interoperability with a PET needs to be carried by the business users. Above all, interoperability with a business user's processes (e.g. a large for-profit organization) may necessitate revealing intricate details about the business itself to a PET developer. These intricate details may reveal a competitive advantage, trade secret or other secrets they would not want their competitors to know. Finally business users may perceive interoperability as additional cost because of additional complexities are introduced into the IT processes of a business. A Cost-Benefit analysis may reveal that the cost for integrating a PET may outweighs accepting the risk. A multitude of issues may form the basis for this barrier and it could be an interesting issue for future research to uncover.

7 Managerial and policy implications

The findings in the previous chapters are mainly of analytical value. While the rationale behind the found results have been explained, this chapter distils the most prudent issues. Indeed, managerial implications and policy recommendations do not entail a quick fix but rather necessitates a persistent change of behaviour. Recommendations are given in a European context and affirms and contrasts earlier recommendations stated by ENISA.

7.1 Consumer PETs adoption and diffusion

Based on the linear regression model for consumer demand, *strict privacy core values* are have of utmost importance as a driving factor for PET adoption and diffusion. Strict privacy core values entails the insurance of uncompromised privacy in a Privacy-Enhancing Technology. While this may seem a redundant remark, many organizations resolve to privacy-invasive practises to acquire funding such as using user data to make a profit. The 50% of organizations agree that public monetary support is needed to support PET development. Meanwhile, only 20% of respondents use subsidies and grants as a primary source of funding. Moreover, applying for grants and subsidies is often experience as a tedious bureaucratic process.

It is advised to the European Union policy makers to both facilitate a less bureaucratic and easy to apply granting procedure in order to support PET development. Especially smaller organizations seem to benefit from such changes. This recommendation is a double edged sword as both the quality and availability of PETs may rise and may attract the much needed (Broersma, 2017) skilled security professionals. A financially supportive environment both creates jobs through new PET projects and attracts new talent because of proximity benefits between organizations.

Based on the linear regression model for consumer demand, the *reliance on (not yet available) 3rd party technology & infrastructure* is a string barriers. Indeed, the pre-diffusion phase of a new technology can be shortened dramatically if somehow existing infrastructure is used (J. Roland Ortt, 2010). When creating a new infrastructure is really necessary either collaboration or European Union support is necessary. Indeed, organizations often do not have the resources to develop and manage an entire system on their own (J. Roland Ortt & Smits, 2006).

This thesis emphasizes a similar recommendation of ENISA (Domingo-Ferrer et al., 2014, p. iv) to publicly co-found infrastructure projects and privacy-supporting components. However, it is also advised to the European Union policy makers to support digital infrastructural developments because of the development difficulties involved for a single organization.

7.2 Business PETs adoption and diffusion

Based on the linear regression model for business demand, *promotion and support of PET development* is the strongest driver. In practise organizations cooperating with policy makers that support PET development and organizations participating in a regional community to promote privacy engineering, is a driving force.

This driver emphasizes a similar recommendation of ENISA (Domingo-Ferrer et al., 2014, p. iv). The managerial implication for organizations is that PET developers should behave as policy entrepreneurs (Kingdon, 1995, pp. 165–190) to promote their solutions to their users. Nevertheless, European Union policy makers, data protection authorities and standardisation bodies should use their authoritative appeal to support the policy entrepreneurs.

The driver *inter-organizational connectedness* is a moderate to strong driver. The factor reflects easy access to technical knowledge, an environment where it is easy to talk about PET development when needed, and cooperation with other PET producing firms. Primarily PET developing organizations themselves shape the environment in which they develop. It is the culture of organizations and the licensing choice and business model that an organization pursues that shapes the extent to which cooperation and easy contact is possible. Consequently this affects the inter-organizational connectedness. However, easy access to technical knowledge is also a task for e.g. universities to show willingness to collaborate with PET developing organisations. And vice versa, willingness of PET developing organizations to seek advice at e.g. universities.

This driver should also be supported by European Union policy makers. Indeed, the GDPR and ENISA research enables adoption and diffusion of PETs. At the same time regulation guaranteeing net neutrality keeps the balance between PET developing organisations and increases the viability of novel PETs due to low entry barriers.

The *strictness of labour laws* is important to allow professionals to focus on developing PETs instead of (latently) be bothered by employment concerns. At the same time PET consuming businesses may like the idea of a stable churn rate as a guarantee of stability in a PET producing organization. Indeed, stricter labour laws are a driver to business PET adoption and diffusion.

While PET producing organizations have the power to shape favourable contracts for their employees, these contracts are secondary to the law. Therefore, it is advised that European Union legislative bodies enable PET development by creating a favourable employment environment or at least give PET producing organizations the means to create such an environment. To some extent this recommendation fits the recommendation made by ENISA (Domingo-Ferrer et al., 2014, p. iv) as well, namely that legislators need to promote privacy and data protection in their norms.

The driver *external guidance* originates from whether data protection authorities, standardization and legislative organizations offer guidance to a PET developing organization. The adoption and diffusion driving property of this factor has been emphasized by ENISA (Domingo-Ferrer et al., 2014, p. iv).

From a policy perspective the data protection authorities, standardization and legislative organizations could provide a forum for concerns and bringing PET producing organizations together. Consequently, this could reinforce the *inter-organizational connectedness* further.

Business demand offers one barrier: *user's ability to try out interoperability*. The factor consists of the ability of users to try out a PET product/service before deciding whether to us it on the one hand, and whether interoperability with other PETs is important on the other hand. It turns out that interoperability can be a barrier to business PET adoption and diffusion. If indeed legal (e.g. contractual) issues impede the demand by businesses then free and open source alternatives having a permissive license could be the solution. PET producing organizations need to scan the market for such opportunities. Again, *inter-organizational connectedness* and weak ties (Granovetter, 1973) can offer such insights among other means (e.g. universities) .

7.3 Conclusion

The European Union has laid out the bedrock for a privacy-respecting environment through directives and regulations, and is a supporter for PETs through e.g. ongoing research (European Union, 2016a) (Hansen et al., 2015) (D' Acquisto et al., 2015) (Domingo-Ferrer et al., 2014).

ENISA even advised that end users themselves need to take action. In contrast, the European Union could take a more active role in facilitating awareness, promotion and especially collaborative effort. Such facilitation could come in the form of a European platform to collaborate and allow PET producers and users to find each other. Especially in the case of weak ties (Granovetter, 1973), that potentially yield novel insights and/or contacts, such a platform would be invaluable.

For PET developers the implications of the consumer demand model shows the most profound issue to consider when developing: adhere to strict privacy by design values. Privacy as a strict core value in the PET products/services have the largest effect on consumer demand and thus adoption & diffusion.

In the initial phases of this research it was believed that strict labour laws would impede adoption & diffusion. Indeed, the risk taking attitude in the United States has been successful as it gave rise to the biggest digital corporations in the world. A risk-averse attitude and strict labour laws could have impeded such rapid growth and success. However, the business demand model shows that strict labour laws seem to drive business PET adoption & diffusion.

8 Discussion and limitations

The analysis and results of the research need to be put into a certain perspective. This chapter describes the demarcations that emphasize to what extent the research is generalizable.

The descriptive statistics have revealed both some affirmations and some limitations of the questionnaire results. Six striking issues include: First, it is confirmed that the majority of the results collected include organizations that produce data communication and storage PETs which corresponds with the aim of the research. This means that the research is generalizable to data communication and data storage PETs. Second, the research seems limited in its ability to be generalized beyond small organizations. Indeed, most organizations that responded are either micro or small organizations. This finding is asserted by multiple descriptive statistics in sub chapter 6.2.2 . Third, respondents understood the questions in the questionnaire well, they are knowledgeable about PETs and are highly educated. This favours the quality of responses and thus the validity of answers given by respondents. Fourth, the research seems limited to mostly European and North American responses. It is unknown whether cultural issue between continents may impact the generalizability of the research. In any case, generalizability of the research is considered to be legitimate for at least Europe and Northern America. Some of the organizations that started in Europe have moved to the United States after some years making some of the responses intertwined with both Europe and the United States. Sixth, most organizations have no revenue growth at all, they depend mostly on bootstrapping. Furthermore, most organizations consider public monetary support necessary for PETs to thrive. It may be that funding options offered by e.g. the European Union are not able to reach organizations that actually need it. In which case these organizations resolve to bootstrapping.

Considering the sample size another limitation of this research can be noticed. The most significant limitation of this research is that the sample size is rather smaller. Even with N=56, there ae numerous questions that have been answered "n/a" (i.e. not available or not applicable), see "Appendix D: Descriptive statistics". For a selection of questions this resulted in a sample size of N=35. Also, against best efforts, some variables from different categories correlated strongly with each other. Left unattended, this would have deteriorated the quality of the linear regression. Another issue is that some questions seem to capture an essence that belongs to another category. Consequently, it is important to check the correlation matrices to see whether questions capture the intended issue.

Another issue that took considerable consideration was the connotation of words and semantics of questions. While many questions have been validated via the literature some questions needed to be developed and validated as part of this thesis. The reviewers, with each their respective field of expertise, gave feedback on test questionnaires. It turned out that, different reviewers interpreted the questions in a multitude of ways. For example, one of the questions asks about uptake of an organization which is

defined in the dictionary (e.g. Dictionary.com) as "apprehension; understanding or comprehension; mental grasp". Meanwhile, another reviewer noted that he understood the question as an increase in sales. To solve such an issue, it was important to have the definition between parentheses to steer respondents to the intended concept.

It may be possibility to achieve higher factor loadings by deleting one variable. Consequently, it may be possible to increase the number of variables included in the linear regression model. Based on the correlation matrix in "Appendix G: Correlation matrix r > 0.45" it can be seen that variable [B01M_D] "My organization has forecasting capabilities about the future market" has moderate correlation strength (around r = 0.5) with 13 other variables. In another iteration of the factor analysis and multiple linear regression modelling it could be suggested to remove the variable B01M_D to increase the quality of the model. Preliminary tests have shown that more variables will be selected as significant in the linear regression. Due to time restrictions the factor analysis and regression model will not be redone.

Concerning the statistical significance of coefficients in the linear regression models, two coefficients are not significant. For consumer demand the coefficient of the factor "Inter-organizational connectedness (ability to exchange knowledge and collaborate)" is not statistically significant. For business demand the coefficient of the factor "User-centric design" is not statistically significant. Because of this, these factors should not be given meaning. However, the factors have still been explored through discussion.

9 Conclusion and future work

The purpose of this thesis is to find the factors that drive and impede the adoption and diffusion of Privacy-Enhancing Technologies. It turned out that the adoption and diffusion of Privacy-Enhancing Technologies (PETs) can be split into PET consumer and PET business demand.

The problem statement is that PETs have not become a standard and have not been widely used components in system design (Domingo-Ferrer et al., 2014, p. iii). The aim of this thesis is to convert the found factors to specific managerial and policy recommendations. Moreover, this thesis affirms and criticises recommendations earlier made by ENISA.

The literature review has revealed that personal data can be divided in private and sensitive data. Moreover, metadata can be considered private and sensitive data as well because it can reveal the exact context of the personal data it describes. The importance of privacy has been explained as a highly contextual concept. Indeed, while individuals rely on the free flow of information to grow, some flow of information needs to be restricted to protect individuals from harm. The importance of PETs is to digitally protect privacy because privacy is an integral part of our society. Also, the definition of Privacy-Enhancing Technologies explicitly excludes so-called PETs that are in fact invasive and organizations that operate privacy invasive services or sell such products.

The main research question is "What factors are drivers and barriers to the adoption and diffusion of Privacy-Enhancing Technologies in private communication and data storage?" The main research question is divided in three sub research questions to answer the main question.

Sub research question (RQ) 1 states: "What relations can be found (i.e. what does the literature state) that describe Privacy-Enhancing Technology (PET) adoption & diffusion in an organizational (e.g. business) setting?" The answer to this question is that the adoption & diffusion of PETs can be conceptually modelled to five categories. The four independent variable categories are:

1. Category B: Business viability and sustainability
2. Category C: Knowledge and innovation environment
3. Category D: Design values
4. Category E: Research and development.

The dependent variable category (category A) is: Adoption and diffusion. Each category holds a set of topics that are related to each other. The model is based on preliminary technology management literature as a basis. In the second iteration ten interviews were analysed for discrepancies, confirmation and fresh perspectives. In the third iteration the privacy literature and adoption & diffusion literature served as a means to validate earlier findings. These three iterations resulted in the final PET adoption & diffusion model. The simplified model and its relations can be viewed in section 3.2.4 .

Sub research question 2 states: "What factors are the most influential drivers and barriers in the adoption and diffusion of Privacy-Enhancing Technologies (PETs) according to producers of PETs?"

For consumer demand it seems that *strict privacy core values* is deemed the most important driver for consumer PETs. The *reliance on (not yet available) 3rd party technology & infrastructure* is the strongest barrier found. A weaker and statistically not significant driver is *Inter-organizational connectedness*.

For business demand it seems that the strongest driver is the *promotion and support of PET development*. Also quite a strong driver is the *inter-organizational connectedness*. Moderately strong drivers are *strictness of labour laws* and *external guidance*. A strong barrier is the *user's ability to try out interoperability*. An almost non-existent factor that is statistically not significant too is *User centric design*.

Sub research question 3 states: "What are policy and managerial implications of the found driver and barriers to the adoption and diffusion of Privacy-Enhancing Technologies?"

This thesis asserts multiple drivers explored by ENISA (Domingo-Ferrer et al., 2014, p. iii). For example, the support by policy makers to promote PETs. Furthermore the importance of guidance from data protection authorities, legislators and standardisation bodies is confirmed by this thesis.

Furthermore, inter-organizational collaboration should be seriously considered by organizations if they haven't done already. It is one of the strongest drivers for business PET adoption and diffusion.

In contrast, interoperability between PETs seem to form a barrier for business PET adoption and diffusion. However, the reason for this is not clarified by the questionnaire results. Possible reasons are legal (e.g. contracts, licensing) issues on the one hand, and the difficulty to create a business case that necessitates actors to share information (e.g. sensitive business information) to enable interoperability on the other hand. Hopefully, inter-organizational collaboration will turn the effect of this barrier around.

For PET developers the implications of the consumer demand model shows the most profound issue to consider when developing: adhere to strict privacy by design values. Privacy as a strict core value in the PET products/services have the largest effect on consumer demand and thus adoption & diffusion.

In the initial phases of this research it was believed that strict labour laws would impede adoption & diffusion. Indeed, the risk taking attitude in the United States has been successful as it gave rise to the biggest digital corporations in the world. A risk-averse attitude and strict labour laws could have impeded such rapid growth and success. However, the business demand model shows that strict labour laws seem to drive business PET adoption & diffusion.

The promotion of PETs by data protection authorities (Domingo-Ferrer et al., 2014, p. 53), the creating user awareness and promotion of PETs by the research community (D' Acquisto et al., 2015, p. 51) are recommendations that seem to be supported by the findings in this thesis. However, it must be added that facilitation would sometimes be better than delegation: the European Union could play a more active (e.g. facilitation) or even leading role in bringing actors together than is portrayed in ENISA recommendations. Such facilitation could come in the form of a European platform to collaborate and allow PET producers and users to find each other. Especially in the case of weak ties (Granovetter, 1973), that potentially yield novel insights and/or contacts, such a platform would be invaluable.

Above all, the European Union could ease the bureaucratic burden for micro and small organizations so they too will profit in greater numbers from public monetary support while minimizing time spent on secondary activities (e.g. paper work). Consequently, more organizations may overcome the difficulties of maintaining or starting a new project which may drive the adoption and diffusion of PETs.

During the writing of this thesis several potentially interesting issues for future research were found.

First and foremost, doing this research with a bigger sample size (N > 100) would be very insightful. Moreover, a more diverse sample of micro, small, medium and large organizations may add extra understanding of PET adoption and diffusion between firms.

Second, a primary driver extracted from the open-ended questions is the news. Especially news items concerning hacks, censorship, the Snowden leaks and hacked competitors are seen as a driving factor. For PET adoption and diffusion. For this research the news (and (social) media in general) have been considered an exogenous factor. However, whether the news can strategically be utilized to favour PET adoption and diffusion could be an interesting research topic.

Third, a growing shortage of skilled cyber security professionals is emerging. An interesting topic for future research would be to find out how the lack of cyber security professionals affects the adoption and diffusion of PETs.

Fourth, the barrier factor for business PET adoption and diffusion that is difficult to grasp is the *ability to try out interoperability*. Indeed, interoperability is considered a driving factor for PET development by many sources. A multitude of issues may form the basis for this barrier and it could be an interesting issue for future research to uncover.

Fifth and finally, future research could also focus on the collaboration between organizations and finance difficulties. How the connectedness between organizations can lead to PETs that have a higher adoption and diffusion.

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Appendix A: Constructs based on technology management literature

Based on the technology management literature taught at Delft University of Technology, including the literature from the specialisations Emerging Technology-based Innovation and Entrepreneurship, and ICT Management a set of five categories were created that form the basis for the conceptual model to drivers and barriers of Privacy-Enhancing Technology innovation. The MoT literature is on occasion supplemented by Center for Information Technology Policy (CITP) at Princeton University findings. Table 38 shows the source (column 1) from which the statement (column 2) is taken. The source can be a course code from MoT, a reference to CITP slides and on occasion external literature found through the snowball method (Verschuren & Doorewaard, 2010, p. 201). How statements are related to PETs is shown in the third column. The fourth column shows the categories that emerged to make sense of the diverse number of found statements in the context of PETs. The fifth column shows preliminary research questions that served as a basis for the conceptual model and questionnaire. The next phase is to find PET specific literature that can validate, invalidate and add to the finding of Table 38. The light blue rows were preliminary categories that seem to emerge when reading the MoT literature. However, in the end the categories Business sustainability (blue), collaboration (yellow), design values (orange), diffusion (purple), environment (green), and research & development (red) were chosen to represent the conceptual model best.

Table 38 Appendix A: constructs based on technology management literature, including Center for Information Technology Policy (CITP) at Princton University

	Source [a]	Statement from MoT literature	How statement is related to PETs	Category	Possible research questions in PET context
1.	CITP slides	Dominant start-up models use Venture Capital funding (CITP slides) + The dominant business model is: freemium, advertisement, subscriptions, donations, licensing (CITP slides)	What funding options do PET projects use?	Business sustainability	What type(s) of funding benefits PET developing organizations best?
2.	SPM9640	Extracting value from novel technologies requires innovations in business practises, firms should prevent novel technologies from being inserted into the company mechanically, rather novel technologies should be part of doing business (Carr, 2003)	Extracting value from the use of novel PETs requires innovations in business practises as well; novel PETs should be part of doing business.	Business sustainability	Does your organization have managerial skills?
3.	CITP slides	The primary reason for abandoning PET innovation and development is a lack of sustainable income (CITP slides)	The primary reason for abandoning PET innovation and development is a lack of sustainable income.	Business sustainability	Is getting funding easy for your organization?
4.	MoT1435	A firm should use a balanced score card to measure financial, customer, internal and innovation performance (Schilling, 2012, pp. 122–123)	PET firms have a high failure rate, measuring performance is of great importance	Business sustainability	A PET innovating organization should use a balanced score card or other performance measuring tool.

	Source [a]	Statement from MoT literature	How statement is related to PETs	Category	Possible research questions in PET context
5.	CITP slides	Many privacy projects fail because the lack of marketing knowledge (CITP slides)	Many privacy projects fail because the lack of marketing knowledge.	Business sustainability	Does your organization have marketing skills?
6.	MoT1461	Having knowledge about finance increases a firm's ability to discriminate between investors that support the firms mission and vision and that don't (Berk & DeMarzo, 2013)	Having knowledge about finance increases a firm's ability to discriminate between investors that support the firm's mission and vision and that don't.	Business sustainability	What type of funding is your organizations primarily using?
7.	MoT1435	Innovation firms should explicitly consider what business model to use (how to make money and add value) to increase the sustainability of innovation and development (Schilling, 2012, pp. 288–289)	Definitely more than general ICT firms because of higher risk of default	Business sustainability	Should Pet innovation be preceded by a business model analysis before actual PET innovation starts?
8.	MoT2421	Focussing on a core competencies will benefit the quality of innovation (J. Roland Ortt & Smits, 2006)	Focussing on a PET core competencies will benefit the quality of PET innovation.	Business sustainability	Does your organization have managerial skills?
9.	CITP slides	The most important barriers to PET innovation are costs and failure rate (CITP slides)	The most important barriers to PET innovation are costs and failure rate. Agree ~ disagree + other?	Business sustainability	The business model for our PET is profitable.
10.	MoT1412	The higher market entry barriers the later a standard is established (Werker, 2003)	Acquiring venture capital for PETs is difficult, because of the high perceived risk and projects that default	Business sustainability	What are the highest market entry barriers for PET innovation? + What is the biggest risk contributing to project failure?
11.	MoT1435	Innovation should be standardized so switching costs between technologies that employ a technology are low (Schilling, 2012, p. 90)	There are many PETs but non-interoperability blocks adoption. Because resources are scares cooperation is needed for a higher chance at PET success	Business sustainability	Should interoperability of PETs be stimulated?
12.	MoT1435	Innovators should deliberate the degree of rivalry, threats and bargaining power to consider the viability of a PET (Schilling, 2012, pp. 110–113)	Only trying to better the world without a focus on keeping the project financially healthy will result in a non-sustainable project	Business sustainability	Should PET entrepreneurs research the market for rivalry, threats and bargaining power before starting a project?
13.	MoT1435	An innovator should focus on its core competencies to differentiate strategically from its competitors (Schilling, 2012, p. 118)	PET innovators should collaborate and use each other's services in order to keep focus on own core competences, not compete, pool resources	Business sustainability	Should PET innovators collaborate and use each other's services, not compete, but instead pool resources?
14.	MoT1435	An innovator should focus on its dynamic capabilities that make a firm more agile and responsive to change in the market (Schilling, 2012, p. 120)	Marketing and managerial skills may be important to Pet development besides technical skills.	Business sustainability	Does your organization have marketing skills? And/or Does your organization have managerial skills?
15.	CITP slides	Demand of the importance of PETs can be established by creating awareness and education (CITP slides)	This means that continuous uptake of the Pet developer itself is also important: find out the needs of customers to create awareness and education that is relevant to customers.	Business sustainability	Has your organization experienced growth in uptake (i.e. understanding, mental grasp) of the PET product/service in the last year?

	Source [a]	Statement from MoT literature	How statement is related to PETs	Category	Possible research questions in PET context
16.	MoT1451	Innovation is a multilateral endeavour requiring a decision-making strategy to stimulate adoption (Teisman, 2000)	Alos, the interviews showed that the interdependency of technologies and importance backward compatibility with legacy protocols is high. Good communication is important.	Collaboration	Does your organization collaborate with other PET developing firms?
17.	**Gürses**	PET efforts should be focussed on systematizing or generalizing approaches so other organizations and engineers can adopt and integrate PETs into their daily practices (S. Gürses & Alamo, 2016)	PET innovation should be focussed on generalizing and context configurability so organizations can adopt and integrate PETs into their daily practises.	Collaboration	Does your PET use existing IT systems and infrastructures?
18.	CITP slides	PETs should be delivered as a 3rd party services for ease of use (CITP slides)	PETs should be delivered as a 3rd party service for ease of use.	Collaboration	Does your organization use PETs developed by other organisations?
19.	CITP slides	There is a reluctance to use 3rd party PETs (CITP slides)	There is a reluctance to use 3rd party PETs.	Collaboration	Does your organization use PETs developed by other organisations?
20.	MoT2421	Collaboration and alliances increase innovation speed and quality (J. Roland Ortt & Smits, 2006)	Collaboration and alliances increase PET innovation speed and quality.	Collaboration	Does your organization collaborate with standardisation bodies, policy makers, and law makers?
21.	MoT1435	Innovation benefits from collaboration such as strategic alliances and joint ventures (Schilling, 2012, pp. 158–160)	PET innovation benefits from collaboration such as strategic alliances and joint ventures.	Collaboration	Does your organization collaborate with universities? Does your organization collaborate with other PET organizations?
22.	MoT1435	Collaborative innovation should be based on a strategic fit and resource fit between firms (Schilling, 2012, p. 166)	PETs are primarily based on norms, values and laws. A strategic fit is of utmost importance to make collaboration sustainable (same goals) and one firm should drag down the other because of a lack of funds	Collaboration	PET organizations should first align their strategic fit and resource fit before starting collaborating.
23.	MoT9591	Collaboration between powerful organizations should lead to industry standards of technologies (Staw, 1992, p. 315)	Collaboration between powerful organizations should lead to industry standards of PETs.	Collaboration	Does your organization collaborate with standardisation bodies, policy makers, and law makers?
24.	SPM9640	Design and innovation should be focused on customers that want to outsource so they can get quickly up to speed and can focus on their core competencies (Willcocks & Plant, 2003)	PETs are rarely a core business of a firm, so leave it to a third party	Collaboration	Should Pet innovation and development be taken care of by a specialized firm so firms can focus on their own core competencies?
25.	MoT1435	Innovation benefits from open innovation (Schilling, 2012, p. 161)	PET innovation suffers from low venture capital due to high risk and thus low resources.	Collaboration	Should PET innovators actively focus on open innovation?
26.	MoT1442	Firms should also contemplate social benefits and costs when developing novel technologies (Poel & Royakkers, 2011, p. 54)	Privacy in itself is a wicked problem and calculating the benefits or costs is even more troublesome due to the contextual and cultural nature of privacy.	Design values	Should the social benefits and costs be calculated before starting a PET project?

	Source [a]	Statement from MoT literature	How statement is related to PETs	Category	Possible research questions in PET context
27.	MoT1451	For novel technologies to be successful, framing issues in terms of heroes and villains helps the adoption rate of technologies (Lakoff, Dean, & Hazen, 2004)	Customers need to know *why* they need a technology. Especially framing the privacy & security issue with heroes and villains is a vivid incentive favouring PETs.	Design values	A company should understand why it is developing PETs and should convey this message to customers.
28.	MoT9591	The process of innovation, standardization and adoption is heavily influenced by the dynamics of the established sociopolitical context and the nature of governmental institutions (Gao, 2014)	Pet innovation, standardization and adoption is heavily influenced by the established socio-political context and the nature of governmental institutions.	Design values	Do laws that don't respect privacy incentivize your organization to create a PET?
29.	CITP slides	User experience and ease of use are the most important factor for adoption of PETs from a user perspective (CITP slides)	Spartan user interfaces are no problem for tech savvy users, but are a problem to the average user.	Design values	Are your customers satisfied with your product/service? What is the most important design value of your product/service (e.g. user interface)?
30.	CITP slides	Pragmatism and trade-offs lead more often to project success than principles, perfection and paranoia (CITP slides)	Perfection impedes the viability and success of a PET because there is always more perfect solution.	Design values	Does your organization have managerial skills to handle tasks efficiently?
31.	MoT1442	There should be a code of conduct at which the design of technology is based (Poel & Royakkers, 2011)	No Code of Conduct currently exists for PET innovation	Design values	Does your organisation consider the law a good form of guidance?
32.	MoT1442	Norms and values should be considered along with their context-dependency and how they affect a technology design (Poel & Royakkers, 2011, pp. 72–74)	Norms and values should be considered along with their context-dependency and how they affect PET design.	Design values	Do data protection authorities guidance play an important role in your PET design?
33.	MoT1451	The privacy problem can be solved given enough technological advances (Rittel & Webber, 1973)	Wicked problem, so cannot be solved, but issue should show the pragmatic approach of an organization: perfection vs viability.	Design values	The privacy problem can be solved given enough technological advances.
34.	MoT1435	Wholly open source systems are good for innovation (Schilling, 2012, p. 191)	For PETs transparency and openness are important to success, so proprietary software do not support this notion. Therefore, open source should be pursued in PET innovation	Design values	Do you offer open access to the inner-workings of your PET product/service?
35.	MoT1435	Backward compatibility is important (Schilling, 2012, p. 287)	Backward compatibility of PETs is important.	Design values	Does your organization consider backward compatibility important? Do you heavily rely on 3rd party infrastructure?
36.	SPM9640	Law and regulation should be taken into consideration when designing and developing technologies (Marston, Li, Bandyopadhyay, Zhang, & Ghalsasi, 2011)	Law and regulation should be taken into consideration when designing and developing PETs	Design values	Are law makers a form of guidance to your organisation? Do laws that not respect privacy incentivize your organization to create PETs?
37.	Gürses	PETs should allow individuals, groups, or institutions to determine for themselves when, how, and to what extent	PETs should allow individuals, groups, or institutions to determine for themselves when,	Design values	Does your PET have automated privacy policy enforcement? Is privacy

	Source [a]	Statement from MoT literature	How statement is related to PETs	Category	Possible research questions in PET context
		information about them is communicated to others (Seda Gürses, 2014)	how, and to what extent information about them is communicated to others.		sometimes an afterthought for your product/service?
38.	SPM9640	Innovation should be aligned with business strategy of the customers and users (Chan & Reich, 2007)	PET innovation should be aligned with business strategy of the customers and users	Design values	Do you use customer feedback to update your development roadmap?
39.	SPM9640	Customer preference factors that are valued the most are: LIST, e.g. pricing & transparency, mobility, reliability, interoperability, scalability, security & quality, time-to-market (Repschlaeger, Erek, & Zarnekow, 2013)	(Moore & Benbasat, 1991) has validated adoption & diffusion question which can be used in the questionnaire.	Design values	What customer preference factors are valued the most? Or: ask Moore paper questions as redundancy for adoption & diffusion questions.
40.	SPM9640	Deploying a technology as an infrastructural technology is able to transform an industry (Carr, 2003)	Deploying a technology as an infrastructural technology is able to transform an industry. But could also impede PETs.	Design values	Does your PET rely on infrastructure that doesn't exist yet?
41.	MoT1412	Potential value conflicts in innovation and their solution should be an *ex ante* integral part of the design process (Taebi, Correljé, Cuppen, Dignum, & Pesch, 2014)	Potential value conflicts in PET innovation and their solution should be an *ex ante* integral part of the PET design process.	Design values	Is privacy sometimes an afterthought in your development process?
42.	MoT1412	Innovating companies should be aware of responsible innovation frameworks to manage what privacy and security entails to society (Stilgoe, Owen, & Macnaghten, 2013)	Norms and values define PETs which are highly contextual and cultural dependent. PET innovating companies should be aware of responsible innovation frameworks to manage what privacy and security entails to society.	Design values	Does your Pet give users more control over their data processing?
43.	MoT2421	Understanding the diffusion process increases adoption of technologies and minimizes wasted efforts on failed market introduction (J. Roland Ortt, 2010)	The interviews show that developers are often focused on perfect big-bang introduction and are not entrepreneurship savvy and completely focused on technology which ultimately results in myopic views and project failure	Diffusion	Successful PET innovation requires an understanding of diffusion of innovation to better see entrepreneurial opportunities.
44.	MoT2421	Novel technology should be introduced in small scale niches to overcome barriers prior to large-scale diffusion (J. Roland Ortt et al., 2013)	PETs should be produced in a niche or be part of a foundation or the like to be protected initially from succumbing market forces.	Diffusion	In what niche would novel PETs have the highest change of survival?
45.	MoT1451	The adoption of technology can be influenced by framing the benefits and drawbacks (Tversky & Kahneman, 1984)	Pre-emptively framing why a certain Pet is important to the public influences adoption positively.	Diffusion	Are your client able to easily explain what your PET does?
46.	MoT1435	Complementary goods based on an technology increase adoption of this technology (Schilling, 2012, p. 27)	The usage of PETs in products or as complementary good increase its usage and thus its adoption, it becomes a new standard of working. PET diffusion will be faster with a higher availability of complementary goods.	Diffusion	Does your Pet has high interoperability/compatibility with other PETs?

	Source [a]	Statement from MoT literature	How statement is related to PETs	Category	Possible research questions in PET context
47.	MoT9591	The usage of existing (technological) infrastructure increases the adoption rate of technologies (J. R. Ortt & Delgoshaie, 2008)	Especially because of the lock-in into decades old Internet protocols, using the existing infrastructure diminishes the effort needed for PET adoption	Diffusion	Should PET innovation be based on existing protocols, rather than creating radically new ones? Does your PET make good use of existing IT infrastructure?
48.	MoT9591	Firms should share their technologies with an alliance and interested businesses to increase adoption rather than keeping proprietary technologies to themselves (Gao, 2014)	Free and Open Source PETs should diffuse much quicker than proprietary close source PETs	Diffusion	Does your organisation license the PET as proprietary or open source? (use a 7 point Likert scale)
49.	MoT1435	Standardization of technology is important (Schilling, 2012, p. 210)	Interoperability of PETs is very important for adoption. Standardization for PETs is important for PETs to successfully diffuse.	Diffusion	Do standardisation bodies form a good source of guidance for your PET?
50.	MoT9591	Innovation should be focused on a dominant design and technological application in multiple technologies in a standardized way (Dao & Zmud, 2013)	PET innovation should be focused on a dominant design and technological application in multiple technologies in a standardized way.	Diffusion	Do standardisation bodies form a good source of guidance for your PET?
51.	MoT1451	Expanding literature on privacy & security concerns will have a positive effect on novel technology awareness and adoption (Lakoff et al., 2004)	When a PET is relatively new, good documentation and support is necessary to promote learning by using.	Environment	Customers consider our PET easy to use.
52.	MoT1435	A successful innovation system consists of heterogeneous actors (i.e. firms, universities, governments, private non-profits, individuals) (Schilling, 2012, p. 19)	A favourable knowledge & innovation environment requires a network of heterogeneous actors (i.e. firms, universities, governments, private non-profits, individuals).	Environment	Does your organisation have easy access to technical knowledge needed for the development of PETs (e.g. from a university or research center)?
53.	CITP slides	PETs should be financed by a foundation that has an overview of relative importance and linkages between projects and interdependencies (CITP slides)	PETs should be financed by a foundation that has an overview of relative importance and linkages between projects and interdependencies.	Environment	Does your organization have easy access to investment capital, including R&D investment?
54.	MoT1435	Geographical proximity increases innovative activity of collaborative networks (Schilling, 2012, p. 33)	Geographical proximity of PET innovators increases innovative activity and collaboration.	Environment	Is your organization part of a regional collaboration effort?
55.	MoT1435	Benefits that firms reap from close geographical proximity are: …….. (Schilling, 2012, p. 34)	Note: A Likert question would be better to analyse than an ordinal list of items.	Environment	Is your organization part of a regional collaboration effort?
56.	MoT1435	Technological spill over, the spread of knowledge across organizational or regional boundaries is good (Schilling, 2012, p. 36)	Especially for PETs because many projects default resulting in lost knowledge.	Environment	Does your organization collaborate with other Pet producing firms?
57.	MoT1524	Social interaction in technology communities enhances the ability to create novel ideas and better understand tasks to be carried out (Newell et al., 2009, p. 170)	Social interaction in PET technology communities enhances the ability to create novel PET ideas and better understand tasks to be carried out. Having multiple perspectives may help in seeing opportunities.	Environment	Is your organization able to find multidisciplinary employees suitable for your organization?

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	Source [a]	Statement from MoT literature	How statement is related to PETs	Category	Possible research questions in PET context
58.	MoT1412	An innovation agglomeration can only be successful if external conditions are actively stimulated (Ooms, Werker, Caniëls, & Bosch, 2015)	Such as European and national innovation system policies and neighbouring regional innovation systems. A PET innovation agglomeration can only be successful if a favourable innovation environment is actively stimulated.	Environment	Does your organization need public support in order to be able to thrive and be successful?
59.	MoT1412	Innovation will benefit from an overlapping knowledge infrastructure between government, industry and universities with hybrid organizations forming at the interfaces (Etzkowitz & Leydesdorff, 2000)	Especially because of the required multidisciplinarity of PETs, a collaboration between stakeholders is beneficial which results in knowledge spill over between stakeholders	Environment	Should government, universities and industry collaborate more intensively on the innovation and development of PETs?
60.	MoT1412	An innovation hub should be situated in an EU state that is either a strong innovator or innovation leader and has shown sustained innovation performance growth over recent years		Environment	What EU state would be most suitable to establish a PET innovation hub?
61.	MoT1451	Introduction relies on a window of opportunity during which the governmental agenda, industry decision agenda and advocates of the novel technology have a simultaneous interest in promoting a technology (Kingdon, 2011)	It is vital that a policy entrepreneur creates a sense of urgency, puts a PET on the agenda and promotes a PET as the solution. It is vital that PETs are promoted as a solution when a problem presents itself in society.	Leadership	
62.	SPM9640	Management should compromise between production efficiency, customer care and technological excellence (Rau, 2004)	Management should compromise between PET production efficiency, customer care and technological excellence of PETs.	Leadership	
63.	MoT9591	Interorganizational network connections need to be formed to increase support for committees and thus increase support for standardization (Bar & Leiponen, 2014)	Inter-organizational network connections need to be formed to increase support for committees and thus increase support for standardization of PETs.	Leadership	
64.	MoT1524	Applied contextual research and development is mode 2 knowledge production (Newell et al., 2009, p. 22) and creating novel solutions is best done in an adhocracy (Newell et al., 2009, p. 36)	PET innovation needs to consider the contextual dependent nature of privacy, and moreover, PET innovation needs to be radically novel due to the increasingly connected world	Leadership	Does PET innovation require applied, contextual, transdisciplinary research more than theoretical single-disciplinary research?
65.	MoT1524	Working in teams yields higher innovative gains than individuals working across projects (Newell et al., 2009, pp. 106–107)	Working in teams om PET innovation yields higher innovative gains than individuals working across PET projects.	Leadership	
66.	MoT1451	The most important ability of a team member is a specific competence (Majone, 1992, p. 4)	In contrast, the interviews show that multi-disciplinary capabilities are more valuable. PETs should be developed in multi-disciplinary teams with non-ICT knowledge and skills.	Research & development	Is it easy for your firm to attract multidisciplinary employees?

	Source [a]	Statement from MoT literature	How statement is related to PETs	Category	Possible research questions in PET context
67.	CITP slides	A lack of interoperability and path dependency leads to every organization reinventing the wheel (e.g. doing own key management) (CITP slides)	PET innovation should exploit the opportunities of novel protocols instead of maintaining decades old protocol backward compatibility.	Research & development	Does your organization develop proprietary PETs? Does your organization use an on-line platform to create and share Pets?
68.	MoT1435	Intellectual property (patents and trade markers) are a necessity to stimulate innovative success (Schilling, 2012, p. 182)	For PETs transparency and openness are important to success, so patents and thus proprietary software do not support this notion. Therefore, intellectual property should not be pursued in PET innovation	Research & development	Do intellectual property (e.g. patents) stimulates PET innovation? Does your organization produce open source PETs?
69.	CITP slides	Weakest links and path dependencies that are aging should be fixed and standardized (e.g. PGP) (CITP slides)	Weakest links and path dependencies that are aging should be fixed and standardized (e.g. PGP) overturning the old technology gracefully.	Research & development	Does your PET heavily rely on 3rd party infrastructure?
70.	MoT1524	The absorptive capacity of a firm to recognize new external information that is of potential value to technologies is important (Newell et al., 2009, p. 83)	The absorptive capacity of an organization to recognize new external information that is of potential value to PET innovation is important.	Research & development	My organization has experienced growth in uptake (i.e. understanding, mental grasp) of the Pet in the last year.
71.	MoT2421	A type of stage-gate innovation management leads to a sustained competitive advantage, shorter launch times, fewer mistakes and less rework in the process (Cooper, 1990b)	Agreeing on what values and norms PETs are built is of the utmost difficulty. Making sure that a stage is entered only when all stakeholders agree a gate is met is especially difficult for PETs	Research & development	My organization defines goals at the start of each project. Deciding at each milestone whether to continue PET innovation and what needs to be completed at the next milestone results in shorter launch times, fewer mistakes and less rework.
72.	MoT1412	Interdisciplinary innovation results in attuned research, innovation and commercialisation respecting societal needs (Taebi et al., 2014)	It is harder to find multidisciplinary people to develop PETs	Research & development	Is it hard to find multidisciplinary developers with the required skills to work on your PET team compared to finding regular ICT developers?
73.	MoT1435	Lead users should be found and involved in innovation and development (Schilling, 2012, p. 240)	Lead users tinker with PETs and try to protect their privacy and improve security in novel ways way ahead of mass market adoption	Research & development	Should PET teams involve lead users in innovation and innovation direction? Or Do you use feedback of your users to update the development roadmap?
74.	MoT9591	Firms constantly need to check how technologies are being used by users across technology application domains to be able to spot new application domains (Levinthal, 1998)	Organizations constantly need to check how PETs are being used by users across technology application domains to be able to spot new application domains.	Research & development	Do you use feedback of your users to update the development roadmap?
75.	MoT1412	Sustained innovation relies on a virtuous circle of social & human capital, research capacity, tech & innovation performance and absorption capacity (Soete, 2007)	Privacy regulation exists, but establishing a virtuous cycle needs action and change while Internet protocols depend heavily on decades old standards	Research & development	What actions are necessary to enable a virtuous cycle of sustained PET innovation?

	Source [a]	Statement from MoT literature	How statement is related to PETs	Category	Possible research questions in PET context
76.	MoT1435	Tacit knowledge and socially complex knowledge are important to the success of innovation (Schilling, 2012, p. 182)	Many Pet projects fail, so to reap benefits in the future socially complex knowledge and tacit knowledge are important to stop history repeating itself	Research & development	How important is tacit knowledge and socially complex knowledge considered to be to PET innovation?
77.	MoT1435	Decentralized R&D in an organic organizational structure leads to the most innovative technologies (Schilling, 2012, p. 212)	Many ideas and forks, based on earlier code, come about every day concerning PETs. Decentralization leads to greater innovative power because of the utilization of weak links in networks leading to novel ideas	Research & development	Should PET research & development be decentralized?
78.	MoT1435	Innovation will benefit from crowdsourcing (Schilling, 2012, p. 241)	Does crowdsourcing lead to greater innovative power than capital venturing?	Research & development	Could PET innovation benefit from crowdsourcing?
79.	MoT1435	Innovation benefits from cross-functional teams (Schilling, 2012, pp. 263–267)	Multidisciplinary is important because PET innovation includes many facets	Research & development	Are cross-functional teams a necessity for PET innovation to be successful?
80.	MoT1435	Innovation benefits from a team that has a diverse background and has diverse skills (Schilling, 2012)	To increase PET installed base, which is already difficult because of decades old standards	Research & development	Does PET innovation benefit from employees with a diverse background?
81.	MoT1524	Proper leadership enhances creative performance of subordinates (Newell et al., 2009, p. 33) by promoting self-discipline, setting a high standard for performance (Newell et al., 2009, p. 44)	PET adoption may be influenced positively by creative leadership.	Stimulate creativity	
82.	MoT1524	Contextual leadership and best practises is key to managing innovation (Newell et al., 2009, p. 149)	Depending on the Pet under development different leadership and business models may be necessary: look at the split from OwnCloud to Nextcloud.	Stimulate creativity	
83.	MoT2421	Contextual and flexible innovation improves innovation efficiency because unnecessary activities are removed and important activities are emphasized depending on type of innovation, organization, industry and country/culture (van der Duin, Ortt, & Aarts, 2014)	Again, good managerial skills seem important. How would that be for PETs?	Stimulate innovation	
84.	MoT2421	Innovation trends need to be analysed at the macro (i.e. country), the meso (i.e. industry) and the micro level (i.e. organisation) to fully grasp innovation opportunities (J. Roland Ortt & Smits, 2006)	Developing PETs in an environment than support privacy may be easier than in an environment where privacy is not important.	Stimulate innovation	
85.	MoT1412	Innovation will benefit from a regional innovation system that includes government, industry, universities, technological centers and transnational corporations (Chaminade & Vang, 2008)	Supports Etzkowitz paper.	Stimulate innovation	
86.	MoT1412	Innovation in Europe way suffer from: infrastructural-, transition-, lock-in-, hard institutional-, soft institutional-, strong network-, weak network- and	Many of the factors are unfortunately counterproductive against PET innovation.	Stimulate innovation	

	Source [a]	Statement from MoT literature	How statement is related to PETs	Category	Possible research questions in PET context
		capabilities- failure, and failure in demand, companies, knowledge institutes or third parties (e.g. VC, banks, consultants) (Klein Woolthuis, Lankhuizen, & Gilsing, 2005)			
87.	MoT9591	Firms that innovate should be offered financial support (Gao, 2014)	Should PETs get public (financial) support via subsidies, grants, etc?	Stimulate innovation	Does your organization need financial support to be successful and thrive?
88.	WM0516	Technology unbundeling, the practise of delineating between science, what a company knows and what potential products are, enables firms to envision new products and services (Floyd, 1997)	Seeing new PET opportunities mean that a team needs to get from behind the monitor and look over boundaries.	Stimulate innovation	Does your organization have managerial skills?
89.	SPM9640	The most important capability in innovation is leadership: integrating efforts into business activities (Chun & Mooney, 2009)		Stimulate innovation	Does your organization have managerial skills?
90.	MoT1451	Decisions made by key actors that could stimulate innovation seem to be aimed at retaining the status quo (Bachrach, 1970)	A collaborating PET community could give incumbent paradigms less chance of becoming too rigid.	Working in teams	Does your organization collaborate with other firms, maybe even via an on-line platform?
91.	MoT1412	The likelihood of innovating new products and services increases when a firm knows when to ask the right what, why, how or who question in the right context (Jensen et al., 2007)	Especially for PETs the context is important.	Working in teams	Does your organization ask why it innovates PETs besides how and what to innovate?
92.	MoT1412	The success of innovation increases when a firm knows existing market knowledge and can envision needed new market knowledge and uses this knowledge to focus on a certain type of innovation (e.g. incremental, radical, architectural, modular) (Popadiuk & Choo, 2006)	Marketing skills might be necessary to identify new opportunities for PET development	Working in teams	Does your organization have marketing skills?
93.	MoT1435	A follower sets the standard more often than a first-mover (Schilling, 2012, p. 94)	Letting other organizations take the risk of innovation could be a good long-term strategy for PET development: copy innovations of other firms. However, who would then take that risk if every firm waits as sees? Pet innovation as a whole would be slow.	Adoption of PETs	Is your organization an innovator or does it rely on other firms to innovate PETs?
94.	MoT9591	Firms should play a proactive role in increasing the willingness to support technologies (Gao, 2014)	How is the PET marketed? Do potential users see the benefits?	Adoption PETs	Does your organization have good marketing skills? Are your customers satisfied with your PET?
95.	SPM9640	Important non-IT roles in technological governance is to communicate strategic direction, ensure realization of business goals, mitigate risk and ensure exceptional technology performance (Rau, 2004)	Do PET producers employee multidisciplinary professionals, is this difficult? It might be good for performance and seeing opportunities compared to single-disciplinary employees.	Adoption PETs	

	Source [a]	Statement from MoT literature	How statement is related to PETs	Category	Possible research questions in PET context
96.	MoT9591	It is important to be aware of factors that either lengthen or shorten the adaption phase of PETs (J. R. Ortt & Delgoshaie, 2008) => 30 factors!	The essence of this research is to find factors that impede or drive adoption & diffusion, so serving a list could be use after creating the model to compare findings.	Adoption PETs	
97.	MoT1412	An innovation has the highest chance of adoption when developed in a protected niche by an existing technological regime (Geels, 2002)	PETs in itself are seldom the core business of a company. However, PETs support business activities in a way that customers value	Adoption PETs : Main	In what environment would the adoption of PETs be positively stimulated?
98.	MoT9591	In order for innovation to become a core capability in Europe, complementary assets such as supplementary bodies of knowledge and skills and increased learning capacity to increase accumulated knowledge and skills are needed (Kash & Rycoft, 2000)	This could be a task for Universities and technology centres to support Pet development.	Collaboration	
99.	MoT2421	Although the current technological developed by your company may be successful, new product development remains a crucial source of competitive advantage for the future (Tushman & Anderson, 1997)	Also, for PETs continuous development may very well be important to continuously add value and stay ahead of competitors.	Research & development	Does your organization update the product roadmap with customer wishes?
100.	MoT1442	Innovators should stress that people have something to fear even when they have done nothing wrong, for example because of errors that could dramatically affect an individual's life (Poel & Royakkers, 2011, p. 129)	This could be measured by an increase in demand, usage and/or sales.	Collaboration between firms	Has your organization noticed an increase in demand for your PET (distinguishing consumers and businesses)?
101.	MoT1435	Developers should be aware of the diffusion of innovation (Schilling, 2012, p. 56)	A perfect PET does no arise instantaneous. Rather is it a process including new norms, value and laws with new iterations	Collaboration between firms	Should PET developers accept the time needed for PET acceptance instead of focussing on a big-bang perfect introduction?
102.	MoT1435	Innovators should consider network externalities (Schilling, 2012, p. 69)	Network externalities could be used to PET innovation's advantage: use feature compatibility at first and build towards a new goal	Collaboration between firms	Should network externalities be embraced as a starting point to build new PETs?
103.	SPM9640	Innovation should be aimed at cloud computing because cost of ownership is low and cloud services are centrally managed allowing technologies to reach many users (Rosenberg & Mateos, 2010)	PET innovation should be aimed at cloud computing because cost of ownership is low and cloud services are centrally managed allowing technologies to reach many users.	Design values	Does your PET ensure increased privacy with big data?
104.	MoT2421	Crossing the valley of death (the segment of development between research and product development) to allow a technology to be a sustained success, requires promoting awareness (champions), support for promising ideas (sponsors) and setting criteria and make acceptance decisions (gatekeepers) (Markham, Ward, Aiman-Smith, & Kingon, 2010)	This is a composite of both marketing, finance and management that may apply to PETs.	Development of PETs	

	Source [a]	Statement from MoT literature	How statement is related to PETs	Category	Possible research questions in PET context
105.	MoT2421	Diffusion is affected by pre-diffusion factors (J. Roland Ortt, 2010, p. 22)	The focus of this research is to find drivers and barriers, where these factors occur exactly could be part of future research.	Diffusion	
106.	MoT2421	Before a mass market strategy should be adopted for novel technologies a wait-and-see strategy could be adopted to bear less risk (J. Roland Ortt et al., 2007)	For PETs however, the development cycle may be much faster than for many other technologies because cyber security is a very fast moving industry: attackers continuously try to break protection mechanisms.	Diffusion	
107.	MoT1461	Technology should be developed by a team with finance awareness such as what a NPV is (Berk & DeMarzo, 2013)	Because of the higher risk and uncertainty of PET innovation, more start-ups fail than in general ICT	Employee hiring: Main	Should the PET team include finance knowledge?
108.	MoT1524	Organizational knowledge among employees is important to efficiently and effectively reach goals (Newell et al., 2009, p. 6)	The alignment of values and norms in PET projects is of heightened importance because they are the main feature	Employees	
109.	MoT9591	Besides product and service innovation, innovating firms should also focus on process innovation (Adner & Levinthal, 2001)	Process innovation for PETs may be of interest, however, insights for this could arise via setting goals and meeting them or not, or reflecting on the process 'why' things are done the way they are done, or by collaborating via an on-line platform and learning-by-doing from this collaborative effort.	Knowledge development	Does your team define goals at the start of a project? Does your team ask why it innovates PETs? Does your organization use an on-line platform to create and share PETs?
110.	MoT9591	A technology consortium would enable both rivalry and complementary companies to benefit from reduced cost of standard development and settling conflicts of interest upfront to formal standardization (Baron & Pohlmann, 2013)	As for now, many PET efforts seem to arise in niches, which means bottom up.	Knowledge development	
111.	WM0516	Lead users face technological needs that will be general in the market place, but face them months or years in advance, therefor lead users are valuable to determine technology trajectory and monetizing opportunities (Urban & Von Hippel, 1988)	This could very well be the case for PETs because tinkering with software is cheap and easy to do.	Knowledge development	

a.   The source of MoT literature statements mostly comes from MoT courses. The course codes belong to the following courses:

MoT1412 - Technology Dynamics   MoT1524 - Leadership and Technology Management
MoT1435 - Technology, Strategy and Entrepreneurship   MoT2421 - Emerging and Breakthrough Technologies
MoT1442 - Social and Scientific Values   SPM9640 - ICT Management
MoT1451 - Inter- and intra-organisational decision making   WM0516 - Turning Technology into Business
MoT1461 - Financial Management   CITP/ Gürses - Center for Information Technology Policy at Princeton

Appendix B: CITP supply-side dynamics

The Dominant Startup model as defined (March 2016) by the Center for Innovation Technology Policy (CITP) at Princeton University and Delft Uinversity of Technology by Hadi Asghari, René Mahieu and Seda Gürses. After comparing the conceptual model created in this thesis and the model by CITP it was noticed that there were similarities and differences.

Compared to the conceptual model in this thesis the category Business viability & sustainability contains Marketing from the CITP model. Furthermore, Abuse and Design trade-offs in the CITP model are one category, namely Design values, in the conceptual model of this thesis. Also, funding and 3rd party services in the CITP model are combined to the Knowledge & innovation environment of the conceptual model of this thesis. Lastly, the conceptual model in this thesis adds one category, namely Research & development.

The CITP model:
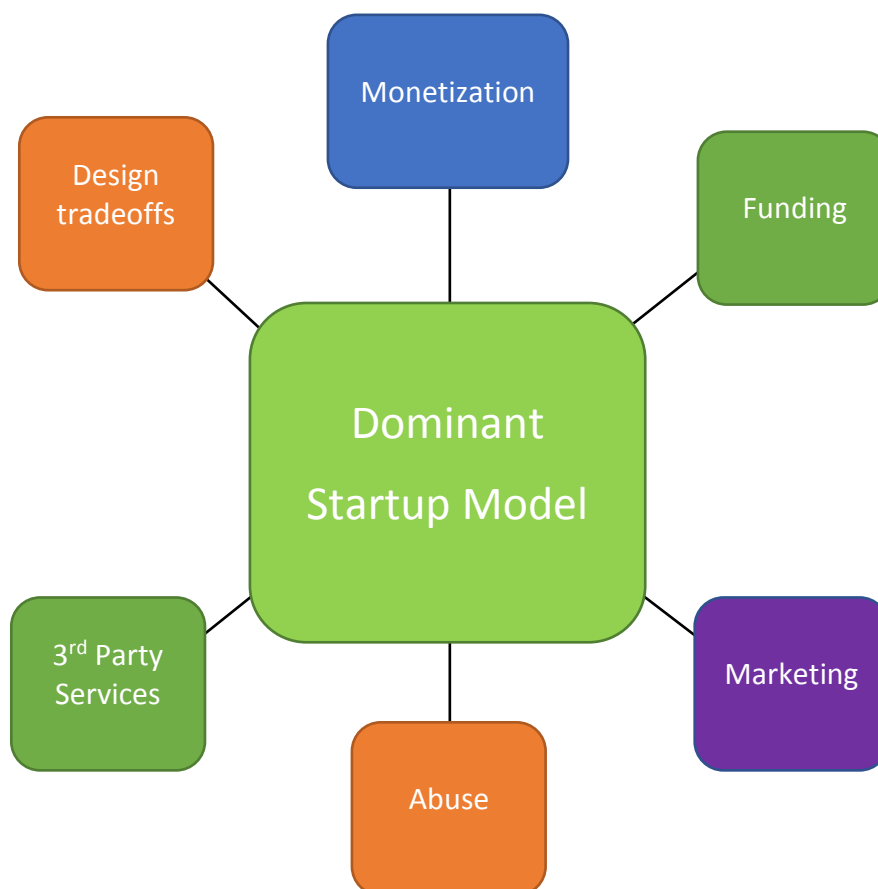
Appendix C: The questionnaire

The questionnaire as it was sent in the last iteration. For some questions a "n/a" (i.e. not available or not applicable) option was added after feedback from respondents. In order to show a compact version of the questionnaire the 7 point Likert scale uses abbreviations in the version displayed in Table 39.

Table 39 Abbreviations used for Likert scale and SPSS values used for options

	Abbreviation	Meaning	Internal value
1.	SD	Strongly Disagree	-3
2.	D	Disagree	-2
3.	SWD	Somewhat Disagree	-1
4.	N	Neither Agree or Disagree	0
5.	SWA	Somewhat Agree	1
6.	A	Agree	2
7.	SA	Strongly Agree	3
9.	N/A	Not available, not applicable	7777777 (SPSS missing value)

The abbreviated references between brackets in the questionnaire were not shown to the respondents; they are included here for reference. The full reference to the abbreviated references can be found in Table 40.

Table 40 The full references that the abbreviated references (between brackets) point to.

	Abbreviated reference	Full reference
1.	Soetanto 2009	(Soetanto, 2009, pp. 126–129)
2.	ENISA 2014	(Domingo-Ferrer et al., 2014)
3.	ENISA 2015	(D' Acquisto et al., 2015)
4.	Salganik 2015	(Salganik, 2017)
		(Salganik & Levy, 2015)
5.	Moore 1991	(Moore & Benbasat, 1991)
6.	Interviews	Questions distilled from interview transcripts/ recordings
7.	Ortt	Dr. Roland Ortt suggestion
8.	Zimmermann	Dr. Phil Zimmermann suggestion
9.	Mahieu	PhD. candidate René Mahieu suggestion

Control questions are marked using a grey background. The literature used to create the control questions originates from a validated questionnaire (van Geenhuizen & Soetanto, 2012, pp. 126–129).

The code of each question has a meaning. For example, the code A02M_E means: the question logically belongs to category A (i.e. Adoption & diffusion) and it is also placed there (because the code begins with only one letter). Furthermore, it is the second main question (see "02"), it is a mandatory question (see "M") and it is sub question E. Whenever a code begins with two letters (e.g. FB) this means that a question belongs logically to the category the first letter indicates (e.g. F = control variable) and was listed in the category indicated by the second letter (e.g. B = Business viability & sustainability). This coding is especially helpful in a later stage of the research where we either confirm or update the

placement of a certain question. When moving questions around to new categories because they seem to fit there better (e.g. based on factor analysis) we still know where the question originates from. Examples of codes and their explanation can be found in Table 41.

Table 41 Code examples and their explanations.

	Code	Belongs to category	Shown in category	Question	Type	Sub question
1.	A02M_C	A: Adoption & Diffusion	A	02	Mandatory	C
2.	D20O	D: Design values	D	20	Optional	-
3.	B10M_15	B: Business viability & sustainability	B	10	Mandatory, with optional input referring to option 15 of question B10M	-
4.	FC12M	F: Control question	C: knowledge & innovation environment	12	Mandatory	-

Seeing "….." in the questionnaire as an answer field means either an open question answer is accepted or when a respondent answers "Other" there is a possibility to explain the choice made.

Pre-start of questionnaire

	Code	Question	Yes	No
1.	G_DEVELOPING	PETs refer to any technology that enhances privacy and control of personal data, information and communication. Are you developing (or have you developed) a Privacy-enhancing Technology (PET)?	○	○

If the answer to G_DEVELOPING is "No" the respondent is forwarded to the following page:

> **Debriefing and request**
>
> We require input from PET developers. Unfortunately you are not developing PETs.
> Please take a minute to spread this questionnaire world-wide among:
> 1. Companies developing PETs (start-ups, SME's, corporations)
> 2. Public and non-profit organizations developing PETs
> 3. Open source PET projects
>
> You can forward this link; we rely on your help to forward this questionnaire:
> <link to questionnaire>
>
> This research tries to find barriers and enablers of PET adoption and diffusion. In case you would like to receive the report, please leave your name and email at <e-mail address>.
> Thank you for your interest!

If the answer to G_DEVELOPING is "Yes" then the questionnaire below starts:

Start of questionnaire

Adoption &
diffusion of innovation
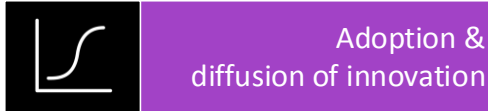
Section 1/5

This first section is about the adoption & diffusion of PET innovation of Privacy-Enhancing Technology (PET) innovation.

	Code	Question	Yes	No
1.	FA01M	Please describe the main Privacy-enhancing product/service of your organization (e.g. VPN, secure email, self-hosted cloud storage, ad blockers, etc) or the PET that you have worked on in the past.	○	○

	Code	Matrix questions	SD	D	SWD	N	SWA	A	SA	N/A
3.a.	A02M_A	The Privacy-Enhancing Technology (PET) product/service we produce is very visible to the market. [Moore 1991]	○	○	○	○	○	○	○	○
3.b.	A02M_B	The demand for our PET product/service by private consumers is high. [Soetanto 2009]	○	○	○	○	○	○	○	○
3.c.	A02M_C	The demand for our PET product/service by private businesses is high. [Soetanto 2009]	○	○	○	○	○	○	○	○
3.d.	A02M_D	The demand for our PET product/service by public organizations is high. [Ortt]	○	○	○	○	○	○	○	○
3.e.	A02M_E	Users would have no difficulty telling others about the results of using our PET product/service. [Moore 1991]	○	○	○	○	○	○	○	○
3.f.	A02M_F	We have noticed a growth in use or sales of the PET product/service in the last year. [Mahieu]	○	○	○	○	○	○	○	○

	Code	Question	Open
4.	A08O	Which other important factors stimulate adoption and diffusion of PETs according to you? Please also indicated if your organization supports them well. [Salganik 2015]	.....

Business viability &
sustainability

Section 2/5

This second section is about Business viability & sustainability of the organization in which the Privacy-Enhancing Technologies (PETs) are created.

	Code	Matrix questions	SD	D	SWD	N	SWA	A	SA	N/A
5.a.	B01M_A	My organization has marketing knowledge. [Soetanto 2009]	○	○	○	○	○	○	○	○
5.b.	B01M_B	My organization has sales skills. [Soetanto 2009]	○	○	○	○	○	○	○	○
5.c.	B01M_C	My organization has managerial skills to handle tasks effectively. [Soetanto 2009]	○	○	○	○	○	○	○	○

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5.d.	B01M_D	My organization has forecasting capabilities about the future market. [Soetanto 2009]	○ ○ ○ ○ ○ ○ ○ ○
5.e.	B01M_E	The business model (i.e. how you earn revenue) of our PET product/service is profitable. [Zimmermann]	○ ○ ○ ○ ○ ○ ○ ○
5.f.	B01M_F	My organization has easy access to investment capital, including R&D investment. [ENISA 2014] [Soetanto 2009]	○ ○ ○ ○ ○ ○ ○ ○
5.g.	B01M_G	Our PET product/service needs monetary public support to develop and thrive. [ENISA 2014, p. iv]	○ ○ ○ ○ ○ ○ ○ ○
5.h.	B01M_H	Getting funding is a very bureaucratic process (e.g. procedures to get grants/subsidies). [ENISA 2014, p. iv]	○ ○ ○ ○ ○ ○ ○ ○
5.i.	B01M_I	Finding risk-taking funders for our PET product/service is easy. [Zimmermann]	○ ○ ○ ○ ○ ○ ○ ○
5.j.	B01M_J	Competition in our market is intense.	○ ○ ○ ○ ○ ○ ○ ○

	Code	Question	Open / Selection
6.	B10M	What is the most important funding option that your organization utilizes for PET projects, excluding revenues from sales & subscriptions? [Interviews]	○ Angel ○ Bank loan ○ Bootstrapping (i.e. your own money) ○ Company sponsors ○ Crowd funding, Reward-based (e.g. Kickstarter) ○ Donations, One-time (e.g. Bitcoins, Paypal) ○ Donations, One-time (e.g. Bitcoins, Paypal) ○ Donations, Recurring micro (e.g. Flattr) ○ Equity from shareholders ○ friends and family ○ Membership platform (e.g. Patreon) ○ Non-profit support (e.g. Mozilla Foundation) ○ Subsidies, Grants (e.g. OTF), Seed Money ○ venture capital ○ Other, ... ○ We don't get any funding
7.	B10bO	How much funding in total was your organization able to acquire for PET projects last year (in Euro), excluding revenues from sales & subscriptions? [Feedback, after 1st wave of responses]	.....
8.	FB11M	Total number of employees/ staff of organization; or if you do not form a legal entity, your organization is the total number of people involved with the PET. [Soetanto 2009]	○ 1 to 9 ○ 10 to 19 ○ 20 to 49 ○ 50 to 99 ○ 100 to 249 ○ 250 to 499 ○ 500 or more
9.	FB12M	Annual revenue in the last year (in Euro). Or if you are a non-profit organization, annual budget. [Soetanto 2009]	○ €0 ○ €1 - €100.000 ○ €100.000 - €400.000 ○ €400.000 – 2M ○ €2M - €10M ○ €10M - €50M ○ €50M - €250M ○ €250M – €1 Billion ○ Above €1 Billion ○ n/a
10.	FB13M	Main source of revenue. Or if you are a non-profit organization, main source of budget spending. [Soetanto 2009]	○ Products ○ Services ○ Consulting ○ Licensing ○ Other ...... %

11.	FB14O	Annual revenue growth (in %) as an average of the ..... last 3 years . Or if you are a non-profit organization, annual budget growth (in %).		

	Code	Question	Open
12.	B15O	Which other important factors do you know for the business viability & sustainability of PET development/deployment? Please indicate how your organization capatilizes on these factors? ..... [Salganik 2015]	

Knowledge & innovation environment

Section 3/5

This third section is about the knowledge & innovation environment in which Privacy-Enhancing Technologies (PETs) are developed.

	Code	Matrix questions	SD	D	SWD	N	SWA	A	SA	N/A
13.a.	C01M_A	My organization has easy access to technical knowledge needed for the development of PETs (e.g from a university or research centre). [ENISA 2014]	○	○	○	○	○	○	○	○
13.b.	C01M_B	My organization is part of an environment where it is easy to talk with anyone we need to, regardless of rank or position. [ENISA 2014]	○	○	○	○	○	○	○	○
13.c.	C01M_C	My organization cooperates with other PET producing firms.	○	○	○	○	○	○	○	○
13.d.	C01M_D	My organization cooperates with policy makers that support the development of PETs. [ENISA 2014, p. iv]	○	○	○	○	○	○	○	○
13.e.	C01M_E	My organization participates in a regional community to promote privacy engineering. [ENISA 2014]	○	○	○	○	○	○	○	○
13.f.	C01M_F	Data protection authorities' guidance plays an important role in our PET design. [ENISA 2014]	○	○	○	○	○	○	○	○
13.g.	C01M_G	Standards (from standardisation bodies) play an important role in our PET design. [ENISA 2014]	○	○	○	○	○	○	○	○
13.h.	C01M_H	The law is an important source of guidance in our PET design. [ENISA 2014]	○	○	○	○	○	○	○	○
13.i.	C01M_I	Our organization experiences too strict employment and labour laws (i.e. protecting employees) that have a negative effect on our innovative abilities. [Zimmermann]	○	○	○	○	○	○	○	○
13.j.	C01M_J	We heavily rely on 3rd party technology (e.g. open source). [Moore 1991]	○	○	○	○	○	○	○	○
13.k.	C01M_K	We require a component or infrastructure that is not available yet.	○	○	○	○	○	○	○	○

	Code	Question	Open
14.	FC12M	In which country is your organization mainly based (i.e. workplace)? Or if that has changed over time, in what country did most development and management decisions take place? [Soetanto 2009]	.....
15.	C13O	Which other important environmental (e.g. market) factors stimulate PETs according to you? Please also state whether they are supported in your organization. [Salganik 2015]	.....

Design values

Section 4/5

This fourth section is about the design values that are considered when developing Privacy-Enhancing Technologies (PETs).

	Code	Matrix questions	SD	D	SWD	N	SWA	A	SA	N/A
16.a.	D01M_A	Customers are satisfied with our PET product/service.	○	○	○	○	○	○	○	○
16.b.	D01M_B	Customers find our PET product/service easy to use. [ENISA 2015, p51]	○	○	○	○	○	○	○	○
16.c.	D01M_C	Users are able to properly try out our PET product/service, before deciding whether to use it. [Moore 1991]	○	○	○	○	○	○	○	○
16.d.	D01M_D	Our PET product/service gives users more control over their personal data processing. [ENISA2015,p6,p16,p22]	○	○	○	○	○	○	○	○
16.e.	D01M_E	Our PET product/service makes good use of existing IT systems (e.g. public key servers, remote servers and clouds).	○	○	○	○	○	○	○	○
16.f.	D01M_F	We offer open access to the inner-workings of our PET product/service (e.g. open source, database access, public auditing). [ENISA 2015, ENISa2014, p45]	○	○	○	○	○	○	○	○
16.g.	D01M_G	Privacy is sometimes an afterthought in our PET product/service design. [ENISA 2015; We know how to make privacy a core part of our design]	○	○	○	○	○	○	○	○
16.h.	D01M_H	Our PET product/service ensures increased privacy with big data. [ENISA 2014, pp.6-7; ENISA 2015,p48]	○	○	○	○	○	○	○	○
16.i.	D01M_I	Data protection authorities' guidance plays an important role in our PET design. [ENISA 2014]	○	○	○	○	○	○	○	○
16.j.	D01M_J	Standards (from standardisation bodies) play an important role in our PET design. [ENISA 2014]	○	○	○	○	○	○	○	○
16.k.	D01M_K	The law is an important source of guidance in our PET design. [ENISA 2014]	○	○	○	○	○	○	○	○
16.l.	D01M_L	Laws that don't respect privacy incentivizes our organization to create PET products/services. [ENISA 2014]	○	○	○	○	○	○	○	○
16.m.	D01M_M	Users are required to use our PET product/service by their superior (e.g. a boss) or by law. [Moore 1991]	○	○	○	○	○	○	○	○
16.n.	D01M_N	Our PET product/service has automated privacy policy enforcement. [ENISA 2015, p. 6]	○	○	○	○	○	○	○	○
16.o.	D01M_O	Our PET product/service does decentralised data analytics. [ENISA 2015, pp. 5-6]	○	○	○	○	○	○	○	○
16.p.	D01M_P	My organization uses PETs that are designed by other organizations. [Moore 1991]	○	○	○	○	○	○	○	○
16.q.	D01M_Q	PET interoperability with other PETs is important. [Moore 1991]	○	○	○	○	○	○	○	○
16.r.	D01M_R	Our PET product/service has high interoperability with other PETs. [Moore 1991]	○	○	○	○	○	○	○	○

	Code	Question
17.	D19M_A	**Under what license is your PET product/service created?**

Completely proprietary			Mixed proprietary and open source			Completely open source
○	○	○	○	○	○	○

	Code	Question	Open
18.	D20O	Do you know other important values to consider in the design, development and deployment of PET products/services? Please state whether these key values play a key role in how your organization operates. [Salganik 2015]	.....

Research & development

Section 5/5

This fifth section is about the Research & development of Privacy-Enhancing Technologies (PETs).

	Code	Matrix questions	SD	D	SWD	N	SWA	A	SA	N/A
19.a.	E01M_A	My organization uses an on-line platform to create and share PETs.	○	○	○	○	○	○	○	○
19.b.	E01M_B	We use feedback of our users to update the development roadmap.	○	○	○	○	○	○	○	○
19.c.	E01M_C	Fixing critical errors and bugs is of highest importance to our PET product/service.	○	○	○	○	○	○	○	○
19.d.	E01M_D	My organization defines goals at the start of each project.	○	○	○	○	○	○	○	○
19.e.	E01M_E	My team is geographically centralized (e.g. working close to each other).	○	○	○	○	○	○	○	○
19.f.	E01M_F	My organization has experienced growth in uptake (i.e. understanding, mental grasp) of the PET product/service in the last year.	○	○	○	○	○	○	○	○
19.g.	E01M_F2	We can easily find employees with technical skills (e.g. computer science and engineering) that are suitable for our organization.	○	○	○	○	○	○	○	○
19.h.	E01M_F3	We can easily find employees with non-technical skills (e.g. economics, law, psychology and ethics) that are suitable for our organization.	○	○	○	○	○	○	○	○
19.i.	E01M_F4	We can easily find employees with multidisciplinary skills (i.e both technical and non-technical skills) that are suitable for our organization. [ENISA 2014, p. iv] [ENISA 2014,p51]	○	○	○	○	○	○	○	○

	Code	Question
20.	E07M_A	**How formalized is your software management process?**

Ad-hoc/ no-process			Agile (e.g. Extreme Programming)			Formal & standardized (e.g. RUP)
○	○	○	○	○	○	○

	Code	Question
21.	E08M_A	**My organization asks itself why it innovates the PET product/service (compared to what and how to innovate). [Jensen, Johnson, Lorenz & Lundvall, 2007; Simon Sinek]**

Never	Rarely	Sometimes but infrequently	Neutral	Sometimes	Usually	Always
○	○	○	○	○	○	○

	Code	Question	Open
22.	FE09M	PET producing experience of your organization (in years). [Soetanto 2009]	.....

	Code	Question	Open
23.	FE10M	Amount of staff involved with PET R&D (in %); for small non-profit open-source projects this is most likely '100' (%). [Soetanto 2009]	.....

	Code	Question	Selection

	Code	Question		
24.	FE11M	I and most of my colleagues have completed... (highest degree completed by most people) [Soetanto 2009]	○ PhD ○ Master ○ Bachelor ○ Vocational education (learning a craft) ○ Secondary school ○ Primary school	

	Code	Question	Open
25.	E12O	Which other important factors do you know for the research & development of PETs? Please state if they are well-facilitated in your organization. [Salganik 2015]	.....

Debriefing

When the questionnaire is filled in, the respondent is shown a final screen with debriefing and some optional questions as seen below.

Debriefing and request

Thank you for your participation!
Please take a minute to spread this questionnaire world-wide among:

1. Companies developing PETs (start-ups, SME's, corporations)
2. Public and non-profit organizations developing PETs
3. Open source PET projects

Your help spreading this questionnaire with this link is much appreciated:
<link to questionnaire>

This research tries to find barriers and enablers of PET adoption and diffusion. In case you would like to receive the report, please leave your name and email at <email address> with the subject "Request for PET report".

	Code	Matrix questions	SD	D	SWD	N	SWA	A	SA	N/A
26.a.	G_UNDERSTAND_A	Please let us know what you think. - The questions in this questionnaire were easy to understand. [Ortt]	○	○	○	○	○	○	○	○
26.b.	G_UNDERSTAND_B	Please let us know what you think. - My knowledge about PETs compared to my colleagues is high. [Ortt]	○	○	○	○	○	○	○	○

	Code	Question	Open
27.	G_JOBPOSITION	What is your job position in your organization (e.g. CEO, lead developer)?	.....
28.	FG01O	How could this questionnaire be made more relevant to your organization? Is there other information you would like to share about your organization?	.....
29.	G_FEEDBACK	If you have feedback for us, please leave your thoughts below. Thank you!	.....

Appendix D: Descriptive statistics

Descriptive statistics of dataset. Only ordinal items are shown, this includes for example the 7-point Likert scale questions. The Likert scale questions are for exploratory reasons treated as interval items.

	N	Range	Minimum	Maximum	Sum	Mean		Std. Deviation	Variance	Skewness		Kurtosis	
	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Statistic	Statistic	Std. Error	Statistic	Std. Error
[A02M_A] The Privacy-enhancing Technology (PET) product/service we produce is very visible to the market.	55	6	-3	3	22	0.40	0.248	1.842	3.393	-0.232	0.322	-1.269	0.634
[A02M_B] The demand for our PET product/service by private consumers is high.	53	6	-3	3	47	0.89	0.230	1.672	2.795	-0.456	0.327	-0.720	0.644
[A02M_C] The demand for our PET product/service by private businesses is high.	52	6	-3	3	40	0.77	0.240	1.733	3.005	-0.569	0.330	-0.671	0.650
[A02M_D] The demand for our PET product/service by public organizations is high.	52	6	-3	3	29	0.56	0.222	1.602	2.565	-0.213	0.330	-0.713	0.650
[A02M_E] Users would have no difficulty telling others about the results of using our PET product/service.	53	5	-2	3	73	1.38	0.187	1.362	1.855	-0.681	0.327	-0.506	0.644
[A02M_F] We have noticed a growth in use or sales of the PET product/service in the last year.	47	5	-2	3	75	1.60	0.212	1.455	2.116	-1.283	0.347	0.995	0.681
[B01M_A] My organization has marketing knowledge.	45	6	-3	3	26	0.58	0.251	1.685	2.840	-0.603	0.354	-0.785	0.695
[B01M_B] My organization has sales skills.	44	6	-3	3	-5	-0.11	0.270	1.794	3.219	0.204	0.357	-1.317	0.702
[B01M_C] My organization has managerial skills to handle tasks effectively.	46	5	-2	3	65	1.41	0.193	1.309	1.714	-1.199	0.350	0.764	0.688
[B01M_D] My organization has forecasting capabilities about the future market.	44	6	-3	3	35	0.80	0.261	1.733	3.004	-0.652	0.357	-0.600	0.702
[B01M_E] The business model (i.e. how you earn revenue) of our PET product/service is profitable.	38	6	-3	3	23	0.61	0.341	2.099	4.408	-0.554	0.383	-1.067	0.750
[B01M_F] My organization has easy access to investment capital, including R&D investment.	39	6	-3	3	-20	-0.51	0.322	2.011	4.046	0.183	0.378	-1.390	0.741
[B01M_G] Our PET product/service needs monetary public support to develop and thrive.	44	6	-3	3	13	0.30	0.292	1.936	3.748	-0.178	0.357	-1.145	0.702
[B01M_H] Getting funding is a very bureaucratic process (e.g. procedures to get grants/subsidies).	38	5	-2	3	55	1.45	0.238	1.465	2.146	-0.898	0.383	-0.034	0.750
[B01M_I] Finding risk-taking funders for our PET product/service is easy.	35	5	-3	2	-20	-0.57	0.263	1.558	2.429	0.215	0.398	-0.999	0.778
[B01M_J] Competition in our market is intense.	45	6	-3	3	11	0.24	0.283	1.897	3.598	0.112	0.354	-1.452	0.695
[BD19M_A] Under what license is your PET product/service created? -	44	6	-3	3	83	1.89	0.309	2.048	4.196	-1.676	0.357	1.362	0.702
[BE01M_F] My organization has experienced growth in uptake (i.e. understanding, mental grasp) of the PET product/service in the last year.	42	5	-2	3	56	1.33	0.198	1.282	1.642	-0.376	0.365	-0.513	0.717
[C01M_A] My organization has easy access to technical knowledge needed for the development of PETs (e.g from a university or research centre).	44	6	-3	3	72	1.64	0.246	1.630	2.655	-1.066	0.357	0.212	0.702
[C01M_B] My organization is part of an environment where it is easy to talk with anyone we need to, regardless of rank or position.	43	6	-3	3	91	2.12	0.195	1.276	1.629	-2.461	0.361	7.235	0.709
[C01M_C] My organization cooperates with other PET producing firms.	43	6	-3	3	38	0.88	0.233	1.531	2.343	-0.756	0.361	0.037	0.709
[C01M_D] My organization cooperates with policy makers that support the development of PETs.	42	6	-3	3	5	0.12	0.279	1.811	3.278	-0.238	0.365	-0.947	0.717
[C01M_E] My organization participates in a regional community to promote privacy engineering.	41	6	-3	3	24	0.59	0.281	1.802	3.249	-0.496	0.369	-0.931	0.724
[C01M_F] Data protection authorities guidance plays an important role in our PET design.	41	6	-3	3	-2	-0.05	0.344	2.202	4.848	0.006	0.369	-1.429	0.724
[C01M_G] Standards (from standardisation bodies) play an important role in our PET design.	43	6	-3	3	15	0.35	0.321	2.103	4.423	-0.148	0.361	-1.340	0.709
[C01M_H] The law is an important source of guidance in our PET design.	43	6	-3	3	-13	-0.30	0.337	2.210	4.883	0.292	0.361	-1.475	0.709
[CD01M_E] Our PET product/service makes good use of existing IT systems (e.g. public key servers, remote servers and clouds).	41	6	-3	3	48	1.17	0.327	2.096	4.395	-0.956	0.369	-0.509	0.724
[CD01M_P] My organization uses PETs that are designed by other organizations.	41	6	-3	3	20	0.49	0.341	2.181	4.756	-0.682	0.369	-1.165	0.724
[D01M_A] Customers are satisfied with our PET product/service.	42	4	-1	3	78	1.86	0.151	0.977	0.955	-0.854	0.365	0.653	0.717
[D01M_B] Customers find our PET product/service easy to use.	43	6	-3	3	42	0.98	0.241	1.581	2.499	-0.643	0.361	-0.381	0.709
[D01M_C] Users are able to properly try out our PET product/service, before deciding whether to use it.	42	6	-3	3	69	1.64	0.259	1.679	2.821	-1.315	0.365	1.056	0.717
[D01M_D] Our PET product/service gives users more control over their personal data processing.	44	3	0	3	113	2.57	0.110	0.728	0.530	-1.763	0.357	2.843	0.702
[D01M_F] We offer open access to the inner-workings of our PET product/service (e.g. open source, database access, public auditing).	42	5	-2	3	95	2.26	0.226	1.466	2.149	-2.186	0.365	3.738	0.717
[D01M_G] Privacy is sometimes an afterthought in our PET product/service design.	43	4	-3	1	-94	-2.19	0.183	1.200	1.441	1.502	0.361	1.468	0.709
[D01M_H] Our PET product/service ensures increased privacy with big data.	39	6	-3	3	47	1.21	0.327	2.041	4.167	-1.036	0.378	-0.191	0.741
[D01M_L] Laws that don't respect privacy incentivizes our organization to create PET products/services.	41	6	-3	3	63	1.54	0.227	1.451	2.105	-0.825	0.369	0.596	0.724
[D01M_M] Users are required to use our PET product/service by their superior (e.g. a boss) or by law.	40	6	-3	3	-30	-0.75	0.299	1.891	3.577	0.338	0.374	-1.102	0.733
[D01M_N] Our PET product/service has automated privacy policy enforcement.	34	6	-3	3	1	0.03	0.369	2.153	4.635	-0.176	0.403	-1.421	0.788
[D01M_O] Our PET product/service does decentralised data analytics.	37	6	-3	3	-31	-0.84	0.381	2.316	5.362	0.601	0.388	-1.337	0.759
[D01M_Q] PET interoperability with other PETs is important.	43	6	-3	3	68	1.58	0.263	1.721	2.963	-1.217	0.361	0.388	0.709
[D01M_R] Our PET product/service has high interoperability with other PETs.	42	6	-3	3	43	1.02	0.267	1.732	2.999	-0.719	0.365	-0.281	0.717
[DE08M_A] My organization asks itself why it innovates the PET product/service (compared to what and how to innovate). -	44	6	-3	3	20	0.45	0.299	1.982	3.928	-0.296	0.357	-1.110	0.702
[E01M_A] My organization uses an on-line platform to create and share PETs.	44	6	-3	3	73	1.66	0.278	1.842	3.393	-1.505	0.357	1.216	0.702
[E01M_B] We use feedback of our users to update the development roadmap.	43	4	-1	3	92	2.14	0.127	0.833	0.694	-1.309	0.361	3.354	0.709
[E01M_C] Fixing critical errors and bugs is of highest importance to our PET product/service.	43	2	1	3	111	2.58	0.089	0.587	0.344	-1.072	0.361	0.232	0.709
[E01M_D] My organization defines goals at the start of each project.	43	6	-3	3	55	1.28	0.243	1.594	2.539	-1.223	0.361	1.140	0.709
[E01M_E] My team is geographically centralized (e.g. working close to each other).	44	6	-3	3	-36	-0.82	0.358	2.375	5.641	0.505	0.357	-1.522	0.702
[E01M_F2] We can easily find employees with technical skills (e.g. computer science and engineering) that are suitable for our organization.	40	5	-3	2	-25	-0.63	0.257	1.628	2.651	0.291	0.374	-1.053	0.733
[E01M_F3] We can easily find employees with non-technical skills (e.g. economics, law, psychology and ethics) that are suitable for our organization.	35	5	-2	3	8	0.23	0.246	1.457	2.123	-0.060	0.398	-1.160	0.778
[E01M_F4] We can easily find employees with multidisciplinary skills (i.e both technical and non-technical skills) that are suitable for our organization.	35	5	-3	2	-28	-0.80	0.238	1.410	1.988	0.358	0.398	-0.807	0.778
[E07M_A] How formalized is your software management process? -	44	6	-3	3	-31	-0.70	0.220	1.456	2.120	0.119	0.357	-0.335	0.702
[EC01M_I] Our organization experiences too strict employment and labour laws (i.e. protecting employees) that have a negative effect on our innovative abilities.	36	6	-3	3	-42	-1.17	0.250	1.502	2.257	0.622	0.393	0.035	0.768
[EC01M_J] We heavily rely on 3rd party technology (e.g. open source).	44	6	-3	3	66	1.50	0.309	2.052	4.209	-1.109	0.357	-0.185	0.702
[EC01M_K] We require a component or infrastructure that is not available yet.	39	6	-3	3	-49	-1.26	0.267	1.666	2.775	0.611	0.378	-0.696	0.741
[FB11M] Total number of employees/ staff of organization; or if you do not form a legal entity, your organization is the total number of people involved with the PET.	46	6	1	7	95	2.07	0.261	1.769	3.129	1.811	0.350	2.394	0.688
[FB12M] Annual revenue in the last year (in Euro). Or if you are a non-profit organization, annual budget.	36	7	1	8	103	2.86	0.279	1.676	2.809	1.157	0.393	1.659	0.768
[FB14O] Annual revenue growth (in %) as an average of the last 3 years . Or if you are a non-profit organization, annual budget growth (in %).	25	320.00	-20.00	300.00	662.79	26.5116	12.79711	63.98556	4094.152	3.589	0.464	14.622	0.902
[FE09M] PET producing experience of your organization (in years).	44	67	2	69	487	11.07	1.644	10.906	118.949	3.724	0.357	18.474	0.702
[FE10M] Amount of staff involved with PET R&D (in %); for small non-profit open-source projects this is most likely '100' (%).	44	98	2	100	2705	61.48	5.915	39.239	1539.697	-0.372	0.357	-1.624	0.702
[G_UNDERSTAND_A] The questions in this questionnaire were easy to understand.	43	3	-1	2	37	0.86	0.097	0.639	0.409	-1.596	0.361	3.790	0.709
[G_UNDERSTAND_B] My knowledge about PETs compared to my colleagues is high.	43	3	-1	2	21	0.49	0.143	0.935	0.875	-0.056	0.361	-0.802	0.709
Valid N (listwise)	8												

Appendix E: Reliability

The Cronbach's Alpha analysis to measure reliability. There is no significant change in the Cronbach's Alpha when a single item is deleted. Above 0.8 is very good reliability.

	Scale Mean if Item Deleted	Scale Variance if Item Deleted	Corrected Item-Total Correlation	Cronbach's Alpha if Item Deleted
[A02M_A] The Privacy-enhancing Technology (PET) product/service we produce is very visible to the market.	47.59	816.882	0.452	0.835
[A02M_B] The demand for our PET product/service by private consumers is high.	47.35	839.993	0.349	0.838
[A02M_C] The demand for our PET product/service by private businesses is high.	47.59	800.507	0.714	0.829
[A02M_D] The demand for our PET product/service by public organizations is high.	48.00	801.625	0.745	0.829
[A02M_E] Users would have no difficulty telling others about the results of using our PET product/service.	46.88	853.235	0.247	0.840
[A02M_F] We have noticed a growth in use or sales of the PET product/service in the last year.	46.76	824.066	0.554	0.834
[B01M_A] My organization has marketing knowledge.	47.35	831.368	0.568	0.835
[B01M_B] My organization has sales skills.	47.65	820.993	0.581	0.833
[B01M_C] My organization has managerial skills to handle tasks effectively.	46.76	847.066	0.381	0.838
[B01M_D] My organization has forecasting capabilities about the future market.	46.88	844.610	0.520	0.837
[B01M_E] The business model (i.e. how you earn revenue) of our PET product/service is profitable.	46.71	827.596	0.583	0.834
[B01M_F] My organization has easy access to investment capital, including R&D investment.	48.24	837.191	0.347	0.838
[B01M_G] Our PET product/service needs monetary public support to develop and thrive.	48.35	885.118	-0.100	0.847
[B01M_H] Getting funding is a very bureaucratic process (e.g. procedures to get grants/subsidies).	47.53	850.640	0.243	0.840
[B01M_I] Finding risk-taking funders for our PET product/service is easy.	48.94	833.309	0.396	0.837
[B01M_J] Competition in our market is intense.	47.41	835.257	0.411	0.837
[BD19M_A] Under what license is your PET product/service created? -	47.47	918.265	-0.303	0.857
[BE01M_F] My organization has experienced growth in uptake (i.e. understanding, mental grasp) of the PET product/service in the last year.	46.76	845.316	0.517	0.837
[C01M_A] My organization has easy access to technical knowledge needed for the development of PETs (e.g from a university or research centre).	47.00	851.625	0.249	0.840
[C01M_B] My organization is part of an environment where it is easy to talk with anyone we need to, regardless of rank or position.	46.53	842.515	0.447	0.837
[C01M_C] My organization cooperates with other PET producing firms.	47.88	827.610	0.463	0.835
[C01M_D] My organization cooperates with policy makers that support the development of PETs.	48.06	797.934	0.768	0.829
[C01M_E] My organization participates in a regional community to promote privacy engineering.	47.76	828.066	0.496	0.835
[C01M_F] Data protection authorities guidance plays an important role in our PET design.	47.82	828.904	0.365	0.837
[C01M_G] Standards (from standardisation bodies) play an important role in our PET design.	47.65	791.493	0.619	0.830
[C01M_H] The law is an important source of guidance in our PET design.	48.00	790.250	0.614	0.830
[CD01M_E] Our PET product/service makes good use of existing IT systems (e.g. public key servers, remote servers and clouds).	46.71	850.221	0.269	0.840
[CD01M_P] My organization uses PETs that are designed by other organizations.	48.47	932.640	-0.421	0.859
[D01M_A] Customers are satisfied with our PET product/service.	46.53	868.765	0.133	0.842
[D01M_B] Customers find our PET product/service easy to use.	47.06	863.059	0.154	0.842
[D01M_C] Users are able to properly try out our PET product/service, before deciding whether to use it.	46.88	850.860	0.251	0.840
[D01M_D] Our PET product/service gives users more control over their personal data processing.	45.76	870.441	0.205	0.841
[D01M_F] We offer open access to the inner-workings of our PET product/service (e.g. open source, database access, public auditing).	46.71	859.221	0.152	0.842
[D01M_G] Privacy is sometimes an afterthought in our PET product/service design.	50.53	908.390	-0.399	0.850
[D01M_H] Our PET product/service ensures increased privacy with big data.	46.71	883.846	-0.088	0.847
[D01M_L] Laws that don't respect privacy incentivizes our organization to create PET products/services.	46.71	846.846	0.405	0.838
[D01M_M] Users are required to use our PET product/service by their superior (e.g. a boss) or by law.	48.76	832.941	0.378	0.837
[D01M_N] Our PET product/service has automated privacy policy enforcement.	48.24	853.566	0.152	0.843
[D01M_O] Our PET product/service does decentralised data analytics.	48.41	828.382	0.315	0.839
[D01M_Q] PET interoperability with other PETs is important.	46.47	859.390	0.226	0.840
[D01M_R] Our PET product/service has high interoperability with other PETs.	46.94	837.059	0.529	0.836
[DE08M_A] My organization asks itself why it innovates the PET product/service (compared to what and how to innovate). -	47.59	865.507	0.089	0.843
[E01M_A] My organization uses an on-line platform to create and share PETs.	47.29	880.221	-0.054	0.848
[E01M_B] We use feedback of our users to update the development roadmap.	46.35	850.868	0.450	0.838
[E01M_C] Fixing critical errors and bugs is of highest importance to our PET product/service.	45.88	860.860	0.563	0.839
[E01M_D] My organization defines goals at the start of each project.	46.47	854.640	0.409	0.839
[E01M_E] My team is geographically centralized (e.g. working close to each other).	48.06	862.309	0.087	0.845
[E01M_F2] We can easily find employees with technical skills (e.g. computer science and engineering) that are suitable for our organization.	49.53	832.640	0.476	0.836
[E01M_F3] We can easily find employees with non-technical skills (e.g. economics, law, psychology and ethics) that are suitable for our organization.	48.00	816.000	0.674	0.832
[E01M_F4] We can easily find employees with multidisciplinary skills (i.e both technical and non-technical skills) that are suitable for our organization.	49.41	848.382	0.340	0.838
[E07M_A] How formalized is your software management process? -	48.82	844.654	0.428	0.837
[EC01M_I] Our organization experiences too strict employment and labour laws (i.e. protecting employees) that have a negative effect on our innovative abilities.	49.24	866.441	0.127	0.842
[EC01M_J] We heavily rely on 3rd party technology (e.g. open source).	47.53	887.140	-0.109	0.849
[EC01M_K] We require a component or infrastructure that is not available yet.	48.94	915.934	-0.423	0.852

Appendix F: Correlation, Adoption & diffusion and Moore's scale questions

The spearman's r correlation matrix of category A questions an all Moore adoption & diffusion scale questions (Moore & Benbasat, 1991). Find Moore scale questions in sub chapter 6.5 , .

Table 16, p. 74.

		[A02M_A] The Privacy-enhancing Technology (PET) product/service we produce is very visible to the market.	[A02M_B] The demand for our PET product/service by private consumers is high.	[A02M_C] The demand for our PET product/service by private businesses is high.	[A02M_D] The demand for our PET product/service by public organizations is high.	[A02M_E] Users would have no difficulty telling others about the results of using our PET product/service.	[A02M_F] We have noticed a growth in use or sales of the PET product/service in the last year.	[D01M_A] Customers are satisfied with our PET product/service.	[D01M_B] Customers find our PET product/service easy to use.	[D01M_C] Users are able to properly try out our PET product/service, before deciding whether to use it.	[D01M_D] Our PET product/service gives users more control over their personal data processing.	[D01M_M] Users are required to use our PET product/service by their superior (e.g. a boss) or by law.	[D01M_Q] PET interoperability with other PETs is important.	[D01M_R] Our PET product/service has high interoperability with other PETs.
[A02M_A] The Privacy-enhancing Technology (PET) product/service we produce is very visible to the market.	Correlation Coefficient	1.000	,457**	,510**	,502**	,299*	,345*	,420**	0.163	0.114	0.036	,385*	0.264	,488**
	Sig. (2-tailed)		0.000	0.000	0.000	0.027	0.016	0.005	0.291	0.465	0.815	0.013	0.084	0.001
	N	57	55	54	54	55	48	43	44	43	45	41	44	43
[A02M_B] The demand for our PET product/service by private consumers is high.	Correlation Coefficient	,457**	1.000	,499**	,372**	,398**	,482**	,335*	,332*	,410**	,347*	0.112	0.217	0.103
	Sig. (2-tailed)	0.000		0.000	0.006	0.003	0.001	0.030	0.030	0.007	0.021	0.484	0.162	0.516
	N	55	55	54	53	54	48	42	43	42	44	41	43	42
[A02M_C] The demand for our PET product/service by private businesses is high.	Correlation Coefficient	,510**	,499**	1.000	,766**	0.175	0.285	0.227	0.113	0.101	0.119	,515**	0.036	0.227
	Sig. (2-tailed)	0.000	0.000		0.000	0.209	0.053	0.153	0.476	0.531	0.446	0.001	0.819	0.153
	N	54	54	54	52	53	47	41	42	41	43	40	42	41
[A02M_D] The demand for our PET product/service by public organizations is high.	Correlation Coefficient	,502**	,372**	,766**	1.000	0.196	0.159	0.257	0.184	0.108	-0.005	,570**	-0.011	0.257
	Sig. (2-tailed)	0.000	0.006	0.000		0.159	0.286	0.104	0.249	0.507	0.975	0.000	0.946	0.105
	N	54	53	52	54	53	47	41	41	40	42	39	42	41
[A02M_E] Users would have no difficulty telling others about the results of using our PET product/service.	Correlation Coefficient	,299*	,398**	0.175	0.196	1.000	,359*	,550**	,459**	,333*	,409**	0.002	0.139	0.278
	Sig. (2-tailed)	0.027	0.003	0.209	0.159		0.013	0.000	0.002	0.033	0.006	0.990	0.380	0.079
	N	55	54	53	53	55	47	41	42	41	43	40	42	41
[A02M_F] We have noticed a growth in use or sales of the PET product/service in the last year.	Correlation Coefficient	,345*	,482**	0.285	0.159	,359*	1.000	,356*	0.150	0.160	0.245	0.028	,443**	,400*
	Sig. (2-tailed)	0.016	0.001	0.053	0.286	0.013		0.028	0.370	0.343	0.133	0.871	0.005	0.013
	N	48	48	47	47	47	48	38	38	37	39	37	39	38
[D01M_A] Customers are satisfied with our PET product/service.	Correlation Coefficient	,420**	,335*	0.227	0.257	,550**	,356*	1.000	,545**	0.304	,327*	0.149	0.226	0.237
	Sig. (2-tailed)	0.005	0.030	0.153	0.104	0.000	0.028		0.000	0.053	0.033	0.358	0.144	0.131
	N	43	42	41	41	41	38	43	43	41	43	40	43	42
[D01M_B] Customers find our PET product/service easy to use.	Correlation Coefficient	0.163	,332*	0.113	0.184	,459**	0.150	,545**	1.000	0.193	,363*	0.181	-0.124	-0.165
	Sig. (2-tailed)	0.291	0.030	0.476	0.249	0.002	0.370	0.000		0.220	0.015	0.259	0.430	0.297
	N	44	43	42	41	42	38	43	44	42	44	41	43	42
[D01M_C] Users are able to properly try out our PET product/service, before deciding whether to use it.	Correlation Coefficient	0.114	,410**	0.101	0.108	,333*	0.160	0.304	0.193	1.000	,374*	-0.031	0.245	0.095
	Sig. (2-tailed)	0.465	0.007	0.531	0.507	0.033	0.343	0.053	0.220		0.014	0.852	0.117	0.554
	N	43	42	41	40	41	37	41	42	43	43	39	42	41
[D01M_D] Our PET product/service gives users more control over their personal data processing.	Correlation Coefficient	0.036	,347*	0.119	-0.005	,409**	0.245	,327*	,363*	,374*	1.000	-0.177	0.108	0.056
	Sig. (2-tailed)	0.815	0.021	0.446	0.975	0.006	0.133	0.033	0.015	0.014		0.267	0.486	0.723
	N	45	44	43	42	43	39	43	44	43	45	41	44	43
[D01M_M] Users are required to use our PET product/service by their superior (e.g. a boss) or by law.	Correlation Coefficient	,385*	0.112	,515**	,570**	0.002	0.028	0.149	0.181	-0.031	-0.177	1.000	-0.004	0.202
	Sig. (2-tailed)	0.013	0.484	0.001	0.000	0.990	0.871	0.358	0.259	0.852	0.267		0.979	0.218
	N	41	41	40	39	40	37	40	41	39	41	41	40	39
[D01M_Q] PET interoperability with other PETs is important.	Correlation Coefficient	0.264	0.217	0.036	-0.011	0.139	,443**	0.226	-0.124	0.245	0.108	-0.004	1.000	,688**
	Sig. (2-tailed)	0.084	0.162	0.819	0.946	0.380	0.005	0.144	0.430	0.117	0.486	0.979		0.000
	N	44	43	42	42	42	39	43	43	42	44	40	44	43
[D01M_R] Our PET product/service has high interoperability with other PETs.	Correlation Coefficient	,488**	0.103	0.227	0.257	0.278	,400*	0.237	-0.165	0.095	0.056	0.202	,688**	1.000
	Sig. (2-tailed)	0.001	0.516	0.153	0.105	0.079	0.013	0.131	0.297	0.554	0.723	0.218	0.000	
	N	43	42	41	41	41	38	42	42	41	43	39	43	43

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

The Pearson's rho correlation matrix of category A questions an all Moore adoption & diffusion scale questions (Moore & Benbasat, 1991). Find Moore scale questions in sub chapter 6.5 , Table 16, p. 73.

		[A02M_A] The Privacy-enhancing Technology (PET) product/service we produce is very visible to the market.	[A02M_B] The demand for our PET product/service by private consumers is high.	[A02M_C] The demand for our PET product/service by private businesses is high.	[A02M_D] The demand for our PET product/service by public organizations is high.	[A02M_E] Users would have no difficulty telling others about the results of using our PET product/service.	[A02M_F] We have noticed a growth in use or sales of the PET product/service in the last year.	[D01M_A] Customers are satisfied with our PET product/service.	[D01M_B] Customers find our PET product/service easy to use.	[D01M_C] Users are able to properly try out our PET product/service, before deciding whether to use it.	[D01M_D] Our PET product/service gives users more control over their personal data processing.	[D01M_M] Users are required to use our PET product/service by their superior (e.g. a boss) or by law.	[D01M_Q] PET interoperability with other PETs is important.	[D01M_R] Our PET product/service has high interoperability with other PETs.
[A02M_A] The Privacy-enhancing Technology (PET) product/service we produce is very visible to the market.	Pearson Correlation	1	,498**	,578**	,544**	,341*	,403**	,419**	0.223	0.029	0.019	,411**	0.164	,398**
	Sig. (2-tailed)		0.000	0.000	0.000	0.011	0.005	0.005	0.146	0.853	0.899	0.008	0.288	0.008
	N	57	55	54	54	55	48	43	44	43	45	41	44	43
[A02M_B] The demand for our PET product/service by private consumers is high.	Pearson Correlation	,498**	1	,520**	,369**	,443**	,443**	0.289	0.284	0.298	,355*	0.139	0.134	0.108
	Sig. (2-tailed)	0.000		0.000	0.006	0.001	0.002	0.064	0.065	0.056	0.018	0.387	0.392	0.496
	N	55	55	54	53	54	48	42	43	42	44	41	43	42
[A02M_C] The demand for our PET product/service by private businesses is high.	Pearson Correlation	,578**	,520**	1	,783**	0.207	,305*	0.186	0.138	0.059	0.096	,480**	-0.011	0.207
	Sig. (2-tailed)	0.000	0.000		0.000	0.136	0.037	0.245	0.385	0.714	0.539	0.002	0.945	0.194
	N	54	54	54	52	53	47	41	42	41	43	40	42	41
[A02M_D] The demand for our PET product/service by public organizations is high.	Pearson Correlation	,544**	,369**	,783**	1	0.235	0.145	0.253	0.185	0.062	-0.001	,566**	-0.114	0.234
	Sig. (2-tailed)	0.000	0.006	0.000		0.091	0.331	0.110	0.247	0.704	0.996	0.000	0.472	0.140
	N	54	53	52	54	53	47	41	41	40	42	39	42	41
[A02M_E] Users would have no difficulty telling others about the results of using our PET product/service.	Pearson Correlation	,341*	,443**	0.207	0.235	1	0.276	,487**	,395**	0.209	,346*	-0.020	0.019	0.196
	Sig. (2-tailed)	0.011	0.001	0.136	0.091		0.061	0.001	0.010	0.191	0.023	0.901	0.906	0.219
	N	55	54	53	53	55	47	41	42	41	43	40	42	41
[A02M_F] We have noticed a growth in use or sales of the PET product/service in the last year.	Pearson Correlation	,403**	,443**	,305*	0.145	0.276	1	0.293	0.168	0.117	0.239	0.087	,418**	,427**
	Sig. (2-tailed)	0.005	0.002	0.037	0.331	0.061		0.074	0.313	0.490	0.142	0.609	0.008	0.008
	N	48	48	47	47	47	48	38	38	37	39	37	39	38
[D01M_A] Customers are satisfied with our PET product/service.	Pearson Correlation	,419**	0.289	0.186	0.253	,487**	0.293	1	,633**	0.142	0.230	0.196	0.129	0.134
	Sig. (2-tailed)	0.005	0.064	0.245	0.110	0.001	0.074		0.000	0.376	0.138	0.224	0.411	0.398
	N	43	42	41	41	41	38	43	43	41	43	40	43	42
[D01M_B] Customers find our PET product/service easy to use.	Pearson Correlation	0.223	0.284	0.138	0.185	,395**	0.168	,633**	1	0.085	0.285	0.264	-0.046	-0.146
	Sig. (2-tailed)	0.146	0.065	0.385	0.247	0.010	0.313	0.000		0.594	0.061	0.096	0.770	0.356
	N	44	43	42	41	42	38	43	44	42	44	41	43	42
[D01M_C] Users are able to properly try out our PET product/service, before deciding whether to use it.	Pearson Correlation	0.029	0.298	0.059	0.062	0.209	0.117	0.142	0.085	1	0.230	-0.003	0.151	-0.063
	Sig. (2-tailed)	0.853	0.056	0.714	0.704	0.191	0.490	0.376	0.594		0.138	0.988	0.339	0.695
	N	43	42	41	40	41	37	41	42	43	43	39	42	41
[D01M_D] Our PET product/service gives users more control over their personal data processing.	Pearson Correlation	0.019	,355*	0.096	-0.001	,346*	0.239	0.230	0.285	0.230	1	-0.146	0.098	0.057
	Sig. (2-tailed)	0.899	0.018	0.539	0.996	0.023	0.142	0.138	0.061	0.138		0.361	0.527	0.717
	N	45	44	43	42	43	39	43	44	43	45	41	44	43
[D01M_M] Users are required to use our PET product/service by their superior (e.g. a boss) or by law.	Pearson Correlation	,411**	0.139	,480**	,566**	-0.020	0.087	0.196	0.264	-0.003	-0.146	1	0.006	0.212
	Sig. (2-tailed)	0.008	0.387	0.002	0.000	0.901	0.609	0.224	0.096	0.988	0.361		0.970	0.194
	N	41	41	40	39	40	37	40	41	39	41	41	40	39
[D01M_Q] PET interoperability with other PETs is important.	Pearson Correlation	0.164	0.134	-0.011	-0.114	0.019	,418**	0.129	-0.046	0.151	0.098	0.006	1	,637**
	Sig. (2-tailed)	0.288	0.392	0.945	0.472	0.906	0.008	0.411	0.770	0.339	0.527	0.970		0.000
	N	44	43	42	42	42	39	43	43	42	44	40	44	43
[D01M_R] Our PET product/service has high interoperability with other PETs.	Pearson Correlation	,398**	0.108	0.207	0.234	0.196	,427**	0.134	-0.146	-0.063	0.057	0.212	,637**	1
	Sig. (2-tailed)	0.008	0.496	0.194	0.140	0.219	0.008	0.398	0.356	0.695	0.717	0.194	0.000	
	N	43	42	41	41	41	38	42	42	41	43	39	43	43

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

Appendix G: Correlation matrix r > 0.45

The correlation matrix below holds the Spearman's r correlation matrix for r > 0.45. The first 4 matrices are partial for easier printed viewing. The 5th matrix is a full matrix for easy PDF viewing/ A3 printing.

The top left part of the matrix (red dashed frames are variables belonging to the same category):

Column variables:
- [A02M_A] The Privacy-enhancing Technology (PET) product/service we produce is very visible to the market.
- [A02M_B] The demand for our PET product/service by private consumers is high.
- [A02M_C] The demand for our PET product/service by private businesses is high.
- [A02M_D] The demand for our PET product/service by public organizations is high.
- [A02M_E] Users would have no difficulty telling others about the results of using our PET product/service.
- [A02M_F] We have noticed a growth in use or sales of the PET product/service in the last year.
- [B01M_A] My organization has marketing knowledge.
- [B01M_B] My organization has sales skills.
- [B01M_C] My organization has managerial skills to handle tasks effectively.
- [B01M_D] My organization has forecasting capabilities about the future market.
- [B01M_E] The business model (i.e. how you earn revenue) of our PET product/service is profitable.
- [B01M_F] My organization has easy access to investment capital, including R&D investment.
- [B01M_I] Finding risk-taking funders for our PET product/service is easy.
- [B01M_J] Competition in our market is intense.
- [BD19M_A] Under what license is your PET product/service created?
- [BE01M_F] My organization has experienced growth in uptake (i.e. understanding, mental grasp) of the PET product/service in the last year.
- [C01M_A] My organization has easy access to technical knowledge needed for the development of PETs.
- [C01M_B] My organization is part of an environment where it is easy to talk with anyone we need to, regardless of rank or position.
- [C01M_D] My organization cooperates with policy makers that support the development of PETs.
- [C01M_E] My organization participates in a regional community to promote privacy engineering.
- [C01M_F] Data protection authorities guidance plays an important role in our PET design.
- [C01M_G] Standards (from standardisation bodies) play an important role in our PET design.
- [C01M_H] The law is an important source of guidance in our PET design.
- [CD01M_P] My organization uses PETs that are designed by other organizations.

Row	Stat	A02M_A	A02M_B	A02M_C	A02M_D	A02M_E	A02M_F	B01M_A	B01M_B	B01M_C	B01M_D	B01M_E	B01M_F	B01M_I	B01M_J	BD19M_A	BE01M_F	C01M_A	C01M_B	C01M_D	C01M_E	C01M_F	C01M_G	C01M_H	CD01M_P
[A02M_A]	Corr	1.000																							
	Sig																								
	N	57																							
[A02M_B]	Corr	,457**	1.000																						
	Sig	0.000																							
	N	55	55																						
[A02M_C]	Corr	,510**	,499**	1.000																					
	Sig	0.000	0.000																						
	N	54	54	54																					
[A02M_D]	Corr	,502**	,372**	,766**	1.000																				
	Sig	0.000	0.006	0.000																					
	N	54	53	52	54																				
[A02M_E]	Corr	0.299*	,398**	0.175	0.196	1.000																			
	Sig	0.027	0.003	0.209	0.159																				
	N	55	54	53	53	55																			
[A02M_F]	Corr	,345*	,482**	0.285	0.159	,359*	1.000																		
	Sig	0.016	0.001	0.053	0.286	0.013																			
	N	48	48	47	47	47	48																		
[B01M_A]	Corr	0.277	0.222	,302*	,351*	0.146	0.277	1.000																	
	Sig	0.066	0.148	0.049	0.022	0.350	0.087																		
	N	45	44	43	42	44	39	46																	
[B01M_B]	Corr	,349*	0.201	,367*	0.334	0.024	0.194	,779**	1.000																
	Sig	0.020	0.197	0.017	0.033	0.878	0.243	0.000																	
	N	44	43	42	41	43	38	44	45																
[B01M_C]	Corr	0.243	0.268	0.193	0.247	0.145	,405**	,402**	,521**	1.000															
	Sig	0.104	0.075	0.209	0.111	0.346	0.009	0.006	0.000																
	N	46	45	44	43	44	40	46	45	47															
[B01M_D]	Corr	,462**	,449**	,496**	,459**	0.222	,505**	,390**	,551**	,590**	1.000														
	Sig	0.002	0.003	0.001	0.003	0.158	0.001	0.008	0.000	0.000															
	N	44	43	42	41	42	38	45	44	45	45														
[B01M_E]	Corr	0.288	0.291	,396*	0.270	0.158	0.264	,378*	,565**	,359*	,482**	1.000													
	Sig	0.079	0.076	0.015	0.106	0.344	0.131	0.021	0.000	0.027	0.003														
	N	38	38	37	37	37	34	37	38	38	37	38													
[B01M_F]	Corr	0.065	-0.028	0.069	0.027	-0.282	0.046	0.292	,434**	,442**	,519**	,428*	1.000												
	Sig	0.694	0.867	0.683	0.876	0.091	0.798	0.076	0.007	0.005	0.001	0.010													
	N	39	38	38	36	37	34	38	38	39	38	35	39												
[B01M_I]	Corr	0.138	0.116	0.333	0.245	-0.252	0.229	0.277	0.213	0.242	0.327	0.100	,604**	1.000											
	Sig	0.421	0.507	0.055	0.163	0.150	0.192	0.101	0.226	0.156	0.055	0.598	0.000												
	N	36	35	34	34	34	34	36	34	36	35	30	33	36											
[B01M_J]	Corr	,329*	,424**	,398**	0.223	0.166	0.249	,384**	,541**	0.238	,441**	,437**	0.226	,404*	1.000										
	Sig	0.028	0.004	0.008	0.151	0.288	0.121	0.009	0.000	0.112	0.003	0.007	0.173	0.015											
	N	45	44	43	43	43	40	45	44	46	44	37	38	36	46										
[BD19M_A]	Corr	-0.148	-0.009	-0.221	-0.196	-0.044	0.012	-,341*	-,434**	-0.210	-0.031	-,595**	0.061	-0.010	-0.268	1.000									
	Sig	0.333	0.953	0.154	0.212	0.778	0.943	0.024	0.004	0.166	0.845	0.000	0.717	0.955	0.079										
	N	45	44	43	42	43	39	44	43	43	43	37	38	35	44	45									
[BE01M_F]	Corr	0.212	0.228	,348*	0.262	,309*	,512**	0.100	,374*	,334*	,455**	0.258	-0.031	0.326	-0.130		1.000								
	Sig	0.173	0.146	0.026	0.098	0.050	0.001	0.528	0.016	0.029	0.003	0.129	0.857	0.776	0.033	0.408									
	N	43	42	41	41	41	39	43	42	44	42	36	37	35	43	43	43								
[C01M_A]	Corr	0.208	0.254	0.090	0.234	,383*	0.243	0.143	-0.109	0.039	0.189	-0.158	0.014	-0.063	0.101	,372*	0.007	1.000							
	Sig	0.170	0.096	0.565	0.135	0.011	0.136	0.354	0.486	0.799	0.224	0.349	0.932	0.717	0.515	0.012	0.967								
	N	45	44	43	43	43	39	44	43	45	43	37	38	35	44	45	43	45							
[C01M_B]	Corr	-0.129	0.231	-0.002	-0.042	0.024	0.109	-0.035	-0.143	0.191	0.020	-0.216	0.154	0.017	-0.076	,414**	-0.185	,494**	1.000						
	Sig	0.404	0.137	0.991	0.792	0.881	0.513	0.826	0.367	0.214	0.902	0.199	0.363	0.922	0.629	0.005	0.242	0.001							
	N	44	43	42	42	42	38	43	42	44	42	37	37	34	43	44	42	44	44						
[C01M_D]	Corr	0.281	0.108	0.272	,345*	0.122	,448**	,394**	,322*	,433**	0.327	0.197	,383*	,412*	0.148	-0.022	0.141	,386*	0.184	1.000					
	Sig	0.067	0.497	0.086	0.027	0.449	0.005	0.009	0.040	0.004	0.035	0.251	0.021	0.015	0.348	0.889	0.379	0.011	0.237						
	N	43	42	41	41	41	37	43	41	43	42	36	36	34	42	43	41	43	43	43					
[C01M_E]	Corr	-0.067	0.054	0.072	0.141	-0.193	0.241	,410**	,332*	0.264	0.111	0.234	0.163	0.279	0.106	-0.071	0.159	0.056	0.123	,559**	1.000				
	Sig	0.673	0.738	0.658	0.385	0.233	0.157	0.008	0.034	0.091	0.489	0.169	0.342	0.116	0.509	0.655	0.328	0.723	0.438	0.000					
	N	42	41	40	40	40	36	41	41	42	41	36	33	41	40	42	42	41	42						
[C01M_F]	Corr	,353*	0.207	0.294	,317*	0.129	0.282	,428**	,582**	,336*	,566**	,450**	0.268	-0.059	0.265	-0.297	0.305	0.101	-0.110	0.283	0.113	1.000			
	Sig	0.022	0.194	0.065	0.046	0.428	0.095	0.005	0.000	0.029	0.000	0.007	0.120	0.744	0.094	0.056	0.055	0.523	0.490	0.069	0.487				
	N	42	41	40	40	40	36	42	40	42	41	35	35	33	41	42	40	42	42	42	41	42			
[C01M_G]	Corr	,332*	0.089	0.197	0.245	-0.018	0.197	0.293	,357*	0.252	,304*	0.149	0.175	0.197	0.190	-0.219	0.119	0.040	-0.046	,430**	0.174	,552**	1.000		
	Sig	0.028	0.572	0.210	0.123	0.912	0.230	0.057	0.020	0.099	0.050	0.387	0.299	0.257	0.222	0.153	0.454	0.798	0.768	0.004	0.278	0.000			
	N	44	43	42	42	42	39	43	42	44	42	36	37	35	43	44	42	44	43	44	41	44	44		
[C01M_H]	Corr	,301*	0.130	,359*	,390*	0.026	0.318	,669**	,716**	,362*	,493**	,428*	,402*	0.307	,496**	-,335*	0.284	0.128	-0.112	,544**	,314*	,685**	,561**	1.000	
	Sig	0.047	0.406	0.020	0.012	0.869	0.052	0.000	0.000	0.016	0.001	0.009	0.014	0.073	0.001	0.026	0.068	0.408	0.473	0.000	0.046	0.000	0.000		
	N	44	43	42	42	42	38	44	42	44	43	36	37	35	43	44	42	44	43	43	41	44	44	44	
[CD01M_P]	Corr	-0.243	-0.273	-0.007	-0.094	-,360*	-0.204	0.059	-0.044	-0.181	0.057	-0.144	0.125	,369*	-0.010	0.079	0.030	-0.150	-0.214	0.014	0.102	-0.262	-0.200	-0.071	1.000
	Sig	0.122	0.084	0.966	0.566	0.023	0.227	0.716	0.789	0.251	0.729	0.408	0.473	0.037	0.949	0.617	0.856	0.344	0.174	0.930	0.533	0.102	0.211	0.658	
	N	42	41	40	40	40	37	42	40	42	42	35	35	32	41	42	40	42	42	40	40	40	41	42	42

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

The bottom left part of the matrix:

Column codes and descriptions:
- [A02M_A] The Privacy-enhancing Technology (PET) product/service we produce is very visible to the market.
- [A02M_B] The demand for our PET product/service by private consumers is high.
- [A02M_C] The demand for our PET product/service by private businesses is high.
- [A02M_D] The demand for our PET product/service by public organizations is high.
- [A02M_E] Users would have no difficulty telling others about the results of using our PET product/service.
- [A02M_F] We have noticed a growth in use or sales of the PET product/service in the last year.
- [B01M_A] My organization has marketing knowledge.
- [B01M_B] My organization has sales skills.
- [B01M_C] My organization has managerial skills to handle tasks effectively.
- [B01M_D] My organization has forecasting capabilities about the future market.
- [B01M_E] The business model (i.e. how you earn revenue) of our PET product/service is profitable.
- [B01M_F] My organization has easy access to investment capital, including R&D investment.
- [B01M_I] Finding risk-taking funders for our PET product/service is easy.
- [B01M_J] Competition in our market is intense.
- [BD19M_A] Under what license is your PET product/service created?
- [BE01M_F] My organization has experienced growth in uptake (i.e. understanding, mental grasp) of the PET product/service in the last year.
- [C01M_A] My organization is part of an environment where it is easy to talk with anyone we need to, regardless of rank or position.
- [C01M_B] My organization participates in a regional community that support the development of PETs.
- [C01M_D] My organization cooperates with policy makers.
- [C01M_E] My organization participates in a regional community to promote privacy engineering.
- [C01M_F] Data protection authorities guidance plays an important role in our PET design.
- [C01M_G] Standards (from standardisation bodies) play an important role in our PET design.
- [C01M_H] The law is an important source of guidance in our PET design.
- [CD01M_P] My organization uses PETs that are designed by other organizations.

Row	Measure	A02M_A	A02M_B	A02M_C	A02M_D	A02M_E	A02M_F	B01M_A	B01M_B	B01M_C	B01M_D	B01M_E	B01M_F	B01M_I	B01M_J	BD19M_A	BE01M_F	C01M_A	C01M_B	C01M_D	C01M_E	C01M_F	C01M_G	C01M_H	CD01M_P
[D01M_A] Customers are satisfied with our PET product/service.	Correlation Coefficient	,420**	,335*	0.227	0.257	,550**	,356*	-0.004	0.004	,322*	,354*	0.216	-0.291	-,364*	-0.046	-0.130	0.284	0.271	0.044	-0.155	-0.181	0.195	0.073	-0.078	-,369*
	Sig. (2-tailed)	0.005	0.030	0.153	0.104	0.000	0.028	0.982	0.978	0.035	0.023	0.212	0.085	0.034	0.772	0.404	0.068	0.078	0.780	0.332	0.264	0.227	0.646	0.624	0.019
	N	43	42	41	41	41	38	42	41	43	41	35	36	34	43	43	42	43	42	40	40	42	42	42	40
[D01M_B] Customers find our PET product/service easy to use.	Correlation Coefficient	0.163	,332*	0.113	0.184	,459**	0.150	0.219	,311*	,326*	0.241	,380*	-0.164	-0.320	,367*	-0.215	,397**	0.225	-0.094	0.039	0.232	0.280	0.199	0.231	-0.226
	Sig. (2-tailed)	0.291	0.030	0.476	0.249	0.002	0.370	0.158	0.045	0.031	0.124	0.022	0.333	0.065	0.016	0.162	0.009	0.142	0.548	0.806	0.145	0.077	0.201	0.136	0.155
	N	44	43	42	42	41	38	43	42	44	42	36	37	34	43	44	42	44	43	41	41	43	43	43	41
[D01M_D] Our PET product/service gives users more control over their personal data	Correlation Coefficient	0.036	,347*	0.119	-0.005	,409**	0.245	-0.049	-0.088	0.075	0.012	0.249	-0.277	-0.217	0.172	-0.098	0.177	0.031	0.120	-0.145	0.130	-0.110	-0.128	-0.166	-0.270
	Sig. (2-tailed)	0.815	0.021	0.446	0.975	0.006	0.133	0.753	0.575	0.623	0.939	0.136	0.092	0.210	0.264	0.521	0.257	0.838	0.440	0.354	0.412	0.488	0.409	0.280	0.084
	N	45	44	43	42	43	39	44	43	45	43	37	38	35	44	45	43	45	44	42	42	44	44	44	42
[D01M_F] We offer open access to the inner-workings of our PET product/service (e.g.	Correlation Coefficient	0.022	-0.053	-0.102	0.026	0.012	-0.116	-0.297	-,368*	-0.138	-0.090	-0.303	-0.169	-0.264	-0.157	,599**	-0.045	,332*	0.299	-0.129	0.036	-0.166	-0.051	-,367*	-0.037
	Sig. (2-tailed)	0.891	0.740	0.526	0.873	0.941	0.493	0.056	0.018	0.378	0.575	0.077	0.324	0.138	0.320	0.000	0.780	0.030	0.054	0.420	0.828	0.306	0.749	0.017	0.818
	N	43	42	41	40	41	37	42	41	43	41	35	36	33	42	43	41	43	42	41	40	40	42	42	41
[D01M_G] Privacy is sometimes an afterthought in our PET product/service design.	Correlation Coefficient	-,328*	-,437**	-0.186	-0.151	-,385*	-0.268	0.291	0.140	-0.098	0.017	-0.154	,443**	,377*	-0.134	0.150	-0.227	0.056	0.035	0.126	0.130	-0.009	0.055	0.235	,464**
	Sig. (2-tailed)	0.030	0.003	0.238	0.345	0.012	0.104	0.055	0.376	0.528	0.915	0.370	0.006	0.026	0.391	0.330	0.149	0.716	0.821	0.419	0.419	0.955	0.728	0.125	0.002
	N	44	43	42	41	42	38	44	42	44	43	36	37	35	43	44	42	44	43	43	41	42	43	44	41
[D01M_H] Our PET product/service ensures increased privacy with big data.	Correlation Coefficient	0.179	0.153	0.134	0.150	0.052	0.197	0.169	0.157	0.191	0.050	0.236	-0.152	-0.340	-0.196	-,355*	0.002	-0.135	-0.061	0.140	0.174	0.259	0.193	0.165	-0.264
	Sig. (2-tailed)	0.270	0.346	0.415	0.362	0.753	0.251	0.305	0.345	0.238	0.764	0.179	0.391	0.057	0.231	0.025	0.990	0.406	0.707	0.396	0.295	0.117	0.234	0.314	0.109
	N	40	40	39	39	39	36	39	38	40	39	34	34	32	39	40	38	40	40	39	38	38	40	39	38
[D01M_L] Laws that don't respect privacy incentivizes our organization to create	Correlation Coefficient	0.006	0.135	0.105	-0.018	0.096	,386*	-0.080	0.005	0.026	0.303	,457**	0.196	-0.198	0.225	0.145	,354*	0.224	0.241	0.017	0.103	0.110	0.033	0.080	-0.121
	Sig. (2-tailed)	0.970	0.399	0.520	0.915	0.557	0.018	0.617	0.975	0.872	0.051	0.006	0.253	0.263	0.152	0.358	0.023	0.155	0.130	0.917	0.529	0.499	0.838	0.614	0.462
	N	42	41	40	40	40	37	42	41	42	40	35	36	34	42	42	41	42	41	41	40	40	41	42	39
[D01M_M] Users are required to use our PET product/service by their superior (e.g. a boss) or	Correlation Coefficient	,385*	0.112	,515**	,570**	0.002	0.028	,322*	,467**	,425**	,493**	,460**	0.267	0.148	0.263	-,374*	0.200	-0.017	-0.211	0.286	0.052	-,612**	,402*	,599**	-0.053
	Sig. (2-tailed)	0.013	0.484	0.001	0.000	0.990	0.871	0.040	0.003	0.006	0.001	0.006	0.127	0.412	0.101	0.016	0.222	0.916	0.192	0.073	0.756	0.000	0.009	0.000	0.753
	N	41	41	40	39	40	37	41	39	41	40	34	34	33	40	41	39	41	40	40	38	39	40	41	38
[D01M_O] Our PET product/service does decentralised data analytics.	Correlation Coefficient	0.106	0.034	0.080	0.044	-0.121	0.111	,472**	,484**	0.227	0.234	,401*	,628**	0.412	,342*	-0.168	-0.066	0.022	0.138	0.253	0.233	,358*	0.129	,522**	-0.032
	Sig. (2-tailed)	0.527	0.840	0.641	0.798	0.476	0.538	0.003	0.002	0.171	0.170	0.023	0.000	0.024	0.036	0.315	0.697	0.897	0.408	0.131	0.171	0.032	0.445	0.001	0.849
	N	38	37	36	37	37	33	37	37	38	36	32	31	30	38	38	37	38	38	37	36	36	37	37	37
[D01M_Q] PET interoperability with other PETs is important.	Correlation Coefficient	0.264	0.217	0.036	-0.011	0.139	,443**	0.056	-0.038	0.160	0.236	-0.022	-0.044	0.067	-0.257	0.216	0.038	-0.021	0.126	0.252	0.083	-0.063	,307*	-0.021	-0.154
	Sig. (2-tailed)	0.084	0.162	0.819	0.946	0.380	0.005	0.713	0.813	0.299	0.132	0.901	0.798	0.703	0.092	0.160	0.808	0.893	0.422	0.107	0.605	0.696	0.045	0.894	0.338
	N	44	43	42	42	42	39	43	42	44	42	36	37	35	44	44	43	44	43	42	41	41	43	43	41
[D01M_R] Our PET product/service has high interoperability with other PETs.	Correlation Coefficient	,488**	0.103	0.227	0.257	0.278	,400*	0.213	0.123	,377*	0.014	0.023	0.074	-0.185	0.068	0.173	0.016	0.046	,374*	0.036	0.163	,347*		0.001	-0.185
	Sig. (2-tailed)	0.001	0.516	0.153	0.105	0.079	0.013	0.176	0.445	0.013	0.056	0.937	0.895	0.678	0.235	0.664	0.475	0.919	0.773	0.016	0.824	0.315		0.994	0.254
	N	41	42	41	41	41	38	41	41	41	36	36	34	43	43	42	41	41	40	40	42	42		42	42
[DE08M_A] My organization asks itself why it innovates the PET product/service	Correlation Coefficient	-0.215	0.113	0.089	0.118	-0.157	0.049	,370*	,426**	,386**	0.246	,378*	0.220	0.151	0.078	-,448**	0.115	-0.288	-0.027	0.220	,516**	0.259	0.237	,311*	0.061
	Sig. (2-tailed)	0.156	0.463	0.570	0.456	0.313	0.769	0.014	0.004	0.009	0.112	0.021	0.184	0.386	0.614	0.002	0.462	0.055	0.860	0.156	0.000	0.098	0.121	0.040	0.702
	N	45	44	43	42	43	39	44	43	45	43	37	38	35	44	45	43	45	44	42	42	44	44	44	42
[E01M_B] We use feedback of our users to update the development roadmap.	Correlation Coefficient	0.134	0.272	0.198	0.216	0.027	,338*	,411**	,346*	0.278	0.174	0.180	0.218	,507**	0.258	-0.151	0.292	0.064	0.034	0.282	,407**	0.295	0.221	,372*	0.009
	Sig. (2-tailed)	0.387	0.077	0.208	0.176	0.865	0.038	0.006	0.025	0.068	0.270	0.293	0.195	0.002	0.095	0.329	0.061	0.678	0.829	0.070	0.008	0.061	0.155	0.014	0.954
	N	44	43	42	41	42	38	43	42	44	42	36	37	34	43	44	42	44	43	42	41	41	43	43	41
[E01M_C] Fixing critical errors and bugs is of highest importance to our PET product/service.	Correlation Coefficient	0.169	,432**	0.251	0.116	,380*	,409**	0.079	0.012	0.002	0.113	0.125	-0.225	-0.067	0.192	0.054	,399**	0.250	0.264	0.100	0.133	0.111	0.079	0.009	-0.048
	Sig. (2-tailed)	0.273	0.004	0.109	0.469	0.013	0.011	0.615	0.942	0.991	0.477	0.468	0.180	0.706	0.216	0.728	0.009	0.101	0.087	0.529	0.405	0.489	0.616	0.953	0.767
	N	44	43	42	41	42	38	43	42	44	42	36	37	34	43	44	42	44	43	42	41	41	43	43	41
[E01M_C] My organization defines goals at the start of each project.	Correlation Coefficient	0.079	,331*	0.233	0.088	0.098	0.275	0.251	,354*	0.182	0.303	,338*	0.104	0.050	,423**	-0.272	,377*	-0.013	0.048	0.139	0.258	,521**	,413**	,387**	-0.068
	Sig. (2-tailed)	0.610	0.030	0.137	0.580	0.535	0.090	0.104	0.022	0.236	0.051	0.044	0.541	0.776	0.004	0.075	0.013	0.935	0.758	0.380	0.103	0.000	0.006	0.010	0.670
	N	44	43	42	42	42	39	43	42	44	42	36	37	35	44	44	43	44	43	42	41	41	43	43	41
[E01M_F2] We can easily find employees with technical skills (e.g. computer science and	Correlation Coefficient	0.028	-0.155	-0.026	0.070	-0.147	0.067	0.154	0.257	0.013	0.005	-0.044	0.314	0.295	0.143	0.142	0.285	0.173	0.002	0.199	0.174	0.145	0.170	0.258	0.096
	Sig. (2-tailed)	0.862	0.333	0.876	0.670	0.367	0.697	0.344	0.115	0.935	0.650	0.798	0.066	0.096	0.379	0.377	0.078	0.280	0.992	0.241	0.284	0.380	0.294	0.109	0.559
	N	41	41	40	40	40	36	40	39	41	39	36	35	33	40	41	41	41	40	40	40	39	40	40	39
[E01M_F3] We can easily find employees with non-technical skills (e.g. economics, law,	Correlation Coefficient	,406*	0.226	,554**	,332*	0.038	,390*	,410**	,585**	0.257	,550**	0.309	,429*	,415*	,349*	-0.081	,404*	0.195	0.175	,405*	0.274	,366*	0.269	,354*	0.156
	Sig. (2-tailed)	0.014	0.185	0.001	0.048	0.826	0.023	0.014	0.000	0.131	0.001	0.085	0.016	0.023	0.037	0.639	0.015	0.255	0.308	0.016	0.111	0.033	0.119	0.037	0.370
	N	36	36	35	36	35	34	35	34	36	34	32	31	30	36	36	36	36	35	35	34	35	35	35	35
[E01M_F4] We can easily find employees with multidisciplinary skills (i.e. both technical and non-	Correlation Coefficient	0.172	0.055	0.091	0.113	-0.082	0.076	0.161	,421*	0.201	0.283	-0.009	,433*	,384*	0.271	0.095	0.324	0.029	-0.025	0.204	0.051	0.303	0.108	0.238	0.154
	Sig. (2-tailed)	0.316	0.751	0.604	0.510	0.639	0.671	0.355	0.013	0.240	0.105	0.959	0.015	0.036	0.109	0.580	0.054	0.868	0.884	0.240	0.770	0.082	0.539	0.170	0.376
	N	36	36	35	36	35	34	35	34	36	34	32	31	30	36	36	36	36	35	35	34	35	35	35	35
[E07M_A] How formalized is your software management process? -	Correlation Coefficient	,300*	0.191	0.299	0.218	0.180	0.134	,403**	,507**	,373*	0.276	,351*	0.231	0.066	,344*	-0.280	0.138	0.075	0.007	,411**	0.115	,582**	,396**	,621**	-0.232
	Sig. (2-tailed)	0.045	0.213	0.051	0.165	0.248	0.414	0.007	0.001	0.012	0.074	0.033	0.164	0.705	0.022	0.062	0.378	0.623	0.962	0.006	0.470	0.000	0.008	0.000	0.139
	N	45	44	43	42	43	39	44	43	45	43	37	38	35	44	45	43	45	44	42	42	44	44	44	42
[EC01M_J] We heavily rely on 3rd party technology (e.g. open source).	Correlation Coefficient	-0.176	-0.200	-,357*	-0.241	0.046	-0.156	-,357*	-,420**	-0.033	-0.200	-,496**	-0.233	-0.234	-,352*	,452**	0.095	0.175	0.216	-0.154	-0.046	-,365*	-0.093	-,431**	0.113
	Sig. (2-tailed)	0.248	0.193	0.019	0.125	0.768	0.344	0.017	0.005	0.827	0.199	0.002	0.160	0.176	0.019	0.002	0.546	0.251	0.159	0.325	0.771	0.018	0.549	0.004	0.477
	N	45	44	43	42	43	39	44	43	45	43	37	38	35	44	45	43	45	44	42	42	44	44	44	42

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

The bottom right part of the matrix (red dashed frames are variables belonging to the same category):

Column variables:
- [D01M_A] Customers are satisfied with our PET product/service.
- [D01M_B] Customers find our PET product/service easy to use.
- [D01M_D] Our PET product/service gives users more control over their personal data processing
- [D01M_F] We offer open access to the inner-workings of our PET product/service (e.g. open source, database access, public auditing).
- [D01M_G] Privacy is sometimes an afterthought in our PET product/service design.
- [D01M_H] Our PET product/service ensures increased privacy with big data.
- [D01M_L] Laws that don't respect privacy incentivizes our organization to create PET products/services.
- [D01M_M] Users are required to use our PET product/service by their superior (e.g. a boss) or by law.
- [D01M_O] Our PET product/service does decentralised data analytics.
- [D01M_Q] PET interoperability with other PETs is important.
- [D01M_R] Our PET product/service has high interoperability with other PETs.
- [DE08M_A] My organization asks itself why it innovates the PET product/service (compared to what and how to innovate). -
- [E01M_B] We use feedback of our users to update the development roadmap.
- [E01M_C] Fixing critical errors and bugs is of highest importance to our PET product/service.
- [E01M_D] My organization defines goals at the start of each project.
- [E01M_F2] We can easily find employees with technical skills (e.g. computer science and engineering) that are suitable for our organization.
- [E01M_F3] We can easily find employees with non-technical skills (e.g. economics, law, psychology and ethics) that are suitable for our organization.
- [E01M_F4] We can easily find employees with multidisciplinary skills (i.e both technical and non-technical skills) that are suitable for our organization.
- [E07M_A] How formalized is your software management process? -
- [EC01M_J] We heavily rely on 3rd party technology (e.g. open source).

		A	B	D	F	G	H	L	M	O	Q	R	DE08M_A	E01M_B	E01M_C	E01M_D	F2	F3	F4	E07M_A	EC01M_J
[D01M_A]	Corr.	1.000																			
	Sig.																				
	N	43																			
[D01M_B]	Corr.	,545**	1.000																		
	Sig.	0.000																			
	N	43	44																		
[D01M_D]	Corr.	,327*	,363*	1.000																	
	Sig.	0.033	0.015																		
	N	43	44	45																	
[D01M_F]	Corr.	0.056	0.062	0.229	1.000																
	Sig.	0.727	0.696	0.140																	
	N	41	42	43	43																
[D01M_G]	Corr.	-,350*	-0.179	-,463**	-0.218	1.000															
	Sig.	0.023	0.251	0.002	0.166																
	N	42	43	44	42	44															
[D01M_H]	Corr.	0.193	0.049	,352*	-0.225	-0.192	1.000														
	Sig.	0.246	0.766	0.026	0.175	0.243															
	N	38	39	40	38	39	40														
[D01M_L]	Corr.	0.266	0.274	,412**	0.299	-0.172	0.051	1.000													
	Sig.	0.093	0.083	0.007	0.061	0.276	0.764														
	N	41	41	42	40	42	37	42													
[D01M_M]	Corr.	0.149	0.181	-0.177	-0.129	-0.013	-0.014	-0.080	1.000												
	Sig.	0.358	0.259	0.267	0.434	0.937	0.935	0.628													
	N	40	41	41	39	41	37	39	41												
[D01M_O]	Corr.	-0.165	-0.128	-0.101	-0.233	0.217	0.184	0.005	0.224	1.000											
	Sig.	0.322	0.445	0.546	0.166	0.196	0.298	0.976	0.196												
	N	38	38	38	37	37	34	36	35	38											
[D01M_Q]	Corr.	0.226	-0.124	0.108	0.083	-0.135	0.232	0.169	-0.004	0.011	1.000										
	Sig.	0.144	0.430	0.486	0.602	0.388	0.156	0.286	0.979	0.947											
	N	43	43	44	42	43	39	42	40	38	44										
[D01M_R]	Corr.	0.237	-0.165	0.056	0.152	-0.169	0.241	-0.024	0.202	-0.029	,688**	1.000									
	Sig.	0.131	0.297	0.723	0.342	0.283	0.145	0.883	0.218	0.865	0.000										
	N	42	42	43	41	42	38	41	39	37	43	43									
[DE08M_A]	Corr.	-0.026	0.231	0.081	-,328*	0.181	0.277	-0.037	,333*	0.177	-0.002	-0.041	1.000								
	Sig.	0.871	0.131	0.598	0.032	0.239	0.083	0.817	0.033	0.286	0.991	0.793									
	N	43	44	45	43	44	40	42	41	38	43	43	45								
[E01M_B]	Corr.	-0.212	0.112	0.134	-0.014	0.135	0.181	-0.018	0.196	0.261	-0.087	-0.009	,347*	1.000							
	Sig.	0.172	0.468	0.386	0.930	0.387	0.271	0.912	0.220	0.114	0.579	0.954	0.021								
	N	43	44	44	42	43	39	41	41	38	43	42	44	44							
[E01M_C]	Corr.	0.137	0.167	,564**	,307*	-,341*	0.174	,413**	-0.132	0.104	0.222	0.200	-0.024	,365*	1.000						
	Sig.	0.383	0.280	0.000	0.048	0.025	0.288	0.007	0.409	0.533	0.152	0.205	0.877	0.015							
	N	43	44	44	42	43	39	41	41	38	43	42	44	44	44						
[E01M_D]	Corr.	0.084	,403**	0.150	-0.190	-0.054	0.216	0.292	0.110	0.218	-0.003	-0.089	,321*	0.205	0.141	1.000					
	Sig.	0.593	0.007	0.330	0.228	0.733	0.186	0.061	0.501	0.189	0.983	0.570	0.034	0.188	0.368						
	N	43	43	44	42	43	39	42	40	38	44	43	44	43	43	44					
[E01M_F2]	Corr.	-0.122	0.002	-0.305	0.166	0.161	-,343*	-0.011	0.074	0.300	-0.101	-0.069	-0.069	0.018	0.135	-0.109	1.000				
	Sig.	0.460	0.988	0.053	0.313	0.320	0.035	0.946	0.660	0.080	0.534	0.677	0.668	0.914	0.406	0.501					
	N	39	40	41	39	40	38	38	38	35	40	39	41	40	40	40	41				
[E01M_F3]	Corr.	0.029	-0.015	-0.159	-0.039	0.212	-0.086	0.256	0.091	0.281	-0.026	0.145	0.165	,365*	0.299	0.327	,389*	1.000			
	Sig.	0.870	0.930	0.356	0.828	0.222	0.635	0.143	0.613	0.120	0.879	0.407	0.337	0.031	0.081	0.051	0.019				
	N	35	36	36	34	35	33	34	33	32	36	35	36	35	35	36	36	36			
[E01M_F4]	Corr.	-0.139	0.004	-,399*	-0.010	0.083	-,512**	-0.107	0.102	0.178	-0.168	-0.052	-0.124	0.007	-0.002	0.074	,769**	,481**	1.000		
	Sig.	0.427	0.983	0.016	0.954	0.637	0.002	0.548	0.572	0.329	0.328	0.766	0.472	0.970	0.992	0.667	0.000	0.003			
	N	35	35	36	34	35	33	34	33	32	36	35	36	35	35	36	36	36	36		
[E07M_A]	Corr.	-0.030	0.262	-0.155	-0.223	-0.084	0.178	-0.123	,519**	0.265	-0.080	0.033	0.208	,307*	-0.132	,413**	0.017	0.167	0.124	1.000	
	Sig.	0.848	0.086	0.309	0.151	0.588	0.271	0.438	0.001	0.107	0.606	0.833	0.171	0.043	0.392	0.005	0.918	0.331	0.471		
	N	43	44	45	43	44	40	42	41	38	44	43	45	44	44	44	41	36	36	45	
[EC01M_J]	Corr.	0.183	0.111	0.148	,550**	-0.125	-0.181	0.003	-0.296	-0.260	0.182	0.072	-0.280	-0.227	0.271	-0.270	0.170	-,346*	-0.025	-,394**	1.000
	Sig.	0.239	0.475	0.332	0.000	0.418	0.263	0.983	0.060	0.115	0.238	0.645	0.062	0.138	0.075	0.076	0.287	0.039	0.885	0.007	
	N	43	44	45	43	44	40	42	41	38	44	43	45	44	44	44	41	36	36	45	45

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

Full matrix for PDF viewing (when zoomed in) or printed one-page A3 viewing.

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).

Appendix H: Full PET adoption & diffusion model

The full PET adoption & diffusion model, including all the relations between constructs. For a condensed version, please see section 3.2.4 on page 30.
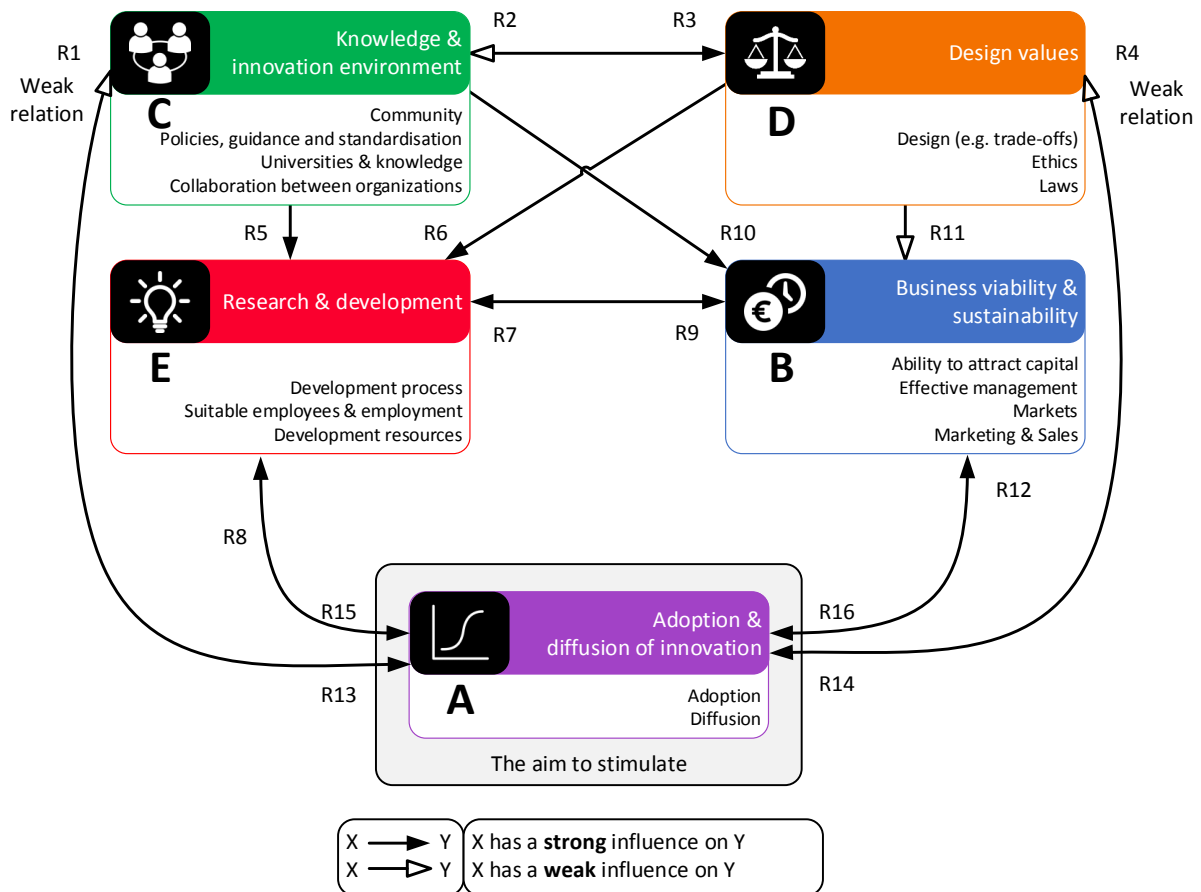

Figure 19 Categories of factors that influence (i.e. drivers and barriers) PET innovation and development (Icons source: Freepik, 2013). A to E means a 'Construct', the R prefix means 'Relation' between constructs.

The relations between constructs in Figure 19 are explained in Table 42.

Table 42 Descriptions of relations and their influences of the conceptual model. See schematic representation of conceptual model in Figure 3.

	Factors influencing ADI [a]	Examples/ Notes	Effects on ADI	Source
R1	Weak influence of A on C	• Once PETs are broadly diffused they influence regimes and the landscape (slow process, a weak relation)	+	(Geels, 2002, p. 1271)
		• A successful PET leads to competitors to copy the technology and the business model (slow process, a weak relation)	+	(J. Roland Ortt et al., 2013, p. 9)
R2	Weak influence of D on C	• Collaborative work on transparency & control compatible with legal obligations	++	(D' Acquisto et al., 2015, p. 50)
		• Technology often precedes law. However, when new regulation comes into effect the environment must obey.	++ or --	(Schilling, 2012, p. 71)
R3	Strong influence of C on D	• It is the environment that decides what the incumbent norms and values are. The ADI depending on the predominant culture.	--	(Geels, 2002, p. 1260)
R4	Weak influence of A on D	• Once PETs are broadly diffused they influence regimes and the landscape which consist of cultural and normative values (slow process, a weak relation)	+	(Geels, 2002, p. 1260)
R5	Strong influence of C on E	• The research community and industry need to combine efforts; policy makers need to promote such efforts. Such collaboration could have a strong effect	++	(D' Acquisto et al., 2015, p. 50)
		• Research community and big data analytics industry need to explore and embody automated enforcement. Such collaboration could have a strong effect.	++	(D' Acquisto et al., 2015, p. 50)
R6	Strong influence of D on E	• The practical application of privacy design and data protection principles	+	(D' Acquisto et al., 2015, p. 49,51)
		• Data protection authorities should provide guidance and tools for privacy engineers	+	(Domingo-Ferrer et al., 2014, p. 53)
		• Interoperability is stimulated by standardisation	+	(Domingo-Ferrer et al., 2014, p. 54)
R7	Strong influence of B on E	• Financial and non-financial performance ensures sustained research & development and the means to pursue strategic objectives	++	(Schilling, 2012, p. 122)
R8	Strong influence of A on E	• If adoption and diffusion of a PET is high R&D on the PET will increase	++	(Schilling, 2012, p. 80)
R9	Strong influence of E on B	• Operational privacy engineering has direct implications on the business model of an organization	++	(Domingo-Ferrer et al., 2014, p. 52)
		• Development capabilities and strategies can all significantly influence the future returns of the development projects	++	(Schilling, 2012, p. 138)
R10	Strong influence of C on B	• Competing with well-established privacy-invasive business models	--	(Domingo-Ferrer et al., 2014, p. 51)
R11	Weak influence of D on B	• Design methodologies should cover non-technological aspects. However, the current PET technology landscape dictates current norms and values. So this relation is weak	+	(Domingo-Ferrer et al., 2014, p. 52)
R12	Strong influence of A on B	• Higher PET adoption generates higher revenues and thus higher viability & sustainability of an organization	++	(Schilling, 2012, p. 80)
R13	Strong influence of C on A	• (H1) An environment that creates PET awareness, uses and adopts PETs leads to diffusion throughout technology regimes and eventually the technology landscape	++	(Geels, 2002), (D' Acquisto et al., 2015, p. 6,51)
		• (H2) Incentive mechanisms promote adoption and diffusion	++ ++	(Domingo-Ferrer et al., 2014, p. 50) (Domingo-Ferrer et al., 2014, pp. 52–53)
		• Infrastructural support allows for lower cost of deploying PETs for all users and operators; which could lead to higher ADI	++	(Domingo-Ferrer et al., 2014, p. 54)
		• Standardisation leads to interoperability and thus usefulness and thus could lead to higher ADI	++	(Domingo-Ferrer et al., 2014, p. 51)
		• Multidisciplinary research in communities lead to more effective PETs and thus could lead to higher ADI	++	(Domingo-Ferrer et al., 2014, p. iii)
		• (H3) Data protection authorities, legislative and standardisation guidance		

	Factors influencing ADI [a]	Examples/ Notes	Effects on ADI	Source
R14	Strong influence of D on A	• (H5) Standardisation leads to interoperability, interoperability leads to adoption	++	(Domingo-Ferrer et al., 2014, p. 54)
		• When PETs respect privacy as envisioned by the user, in respect of reliability and usability, awareness and thus could increase ADI	++	(D' Acquisto et al., 2015, p. 51)
R15	Strong influence of E on A	• Automated policy enforcement, that forces other parties to honour a privacy policy creates trust and could increase ADI	++	(D' Acquisto et al., 2015, p. 6)
		• When R&D is done transparently and users can check the code (e.g. open source) trust in a PET increases and thus its adoption and diffusion	++	(D' Acquisto et al., 2015, p. 6,13)
		• PET novelty and complementarities creates value for customers	++	(Amit & Zott, 2001)
		• (H6) Agile, dynamic capabilities allow to respond to fast-changing PET markets and thus captures user demand for features and bug fixes faster	++	(Schilling, 2012, p. 120)
R16	Strong influence of B on A	• (H4) (H7) When a company is trusted due to good management and financial performance, faster idea-to-market is possible with fewer mistakes and could increase adoption	++	(Schilling, 2012, p. 242), (Cooper, 1990a, p. 44)

a. ADI = Adoption and Diffusion of Innovation