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How Do Thinking Style and Motivation Influence Household Sector Innovation? Evidence from a Cross-Country Survey

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Abstract. Household sector innovations, as a subset of user innovations, are not only an essential driver of economic development and social welfare, but also a good proxy for the ability of people to innovate. Previous research on the individual-level determinants of household sector innovation is limited. Our study contributes to fill this gap and investigates the role of thinking style as well as learning and career motivation as determinants of household sector innovation. Based on a sample of 451 individuals from Taiwan, China, Vietnam, Germany and Japan, we find that people with a better ability in critical thinking and a more intrinsic learning motivation are more likely to be household sector innovators. These persons also put more emphasis on innovation as a career choice motive. Another important finding of our study is that gender differences seem to be smaller for household sector innovation, compared to more traditional forms of innovation. This suggests that this type of innovation provides opportunities for women to play a more prominent role in the economic process, particularly in developing countries.

Keywords: household sector innovation, critical thinking, learning motivation, career motivation, cross-country.

1. Introduction

Household sector and user innovations are widespread and essential drivers of economic development and social welfare (Henkel and Von Hippel, 2004; Gambardella, Raasch and Von Hippel, 2017). User innovation is an important source of entrepreneurial and commercially attractive ideas (Block, Henkel, Schweisfurth, and Stiegler, 2016; Franke, Von Hippel, and Schreier, 2006). Some, but not all user innovators, commercialize these ideas on their own and engage in (innovative) entrepreneurship (Cuomo, Tortora, Festa, Giordano, and Metallo, 2017; Shah and Tripsas, 2007). Recent surveys from different countries show that large numbers of individuals engage in modifying or developing

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products at home (Ogawa and Pongtanalert, 2011; Von Hippel, De Jong and Flowers 2012; Kim, 2015; Fursov, Thurner and Nefedova, 2017; Von Hippel, 2017; Chen, Su, De Jong and Von Hippel, 2020). These *household sector innovators* add significant value to the economy and society. Our study aims to better understand the individual-level determinants of household innovation, in particular with regard to psychology and career choice decisions.

Individuals develop novel solutions when they are intrinsically motivated (Grant and Berry, 2011) and desire to learn and explore new fields (Hirst, Van Knippenberg and Zhou, 2009). However, an innovative talent's characteristics are diverse because there is no single mold into which innovative individuals fit. There appear to be specific cognitive skills dominant in the creative process that are important, as well as intrinsic motivation. Prior research on the individual-level determinants of household sector innovation has explored the links between household sector innovation and gender, technical background (e.g., Von Hippel et al., 2012), income (e.g., Chen et al., 2020), hedonic and utilitarian motives (e.g., Stock, Oliveira and Von Hippel, 2015), and personality traits (e.g., Stock, Von Hippel and Gillert, 2016). Critical thinking, as well as learning and career motivation as important psychological and motivational constructs, have not been explored so far. This is an important gap in the literature, as creativity research and the investment theory of creativity (Sternberg and Lubart, 1991) show that thinking style and learning motivation play important roles in generating creative and innovative ideas.

Our study uses survey data from respondents from Taiwan, Mainland China, Vietnam, Germany, and Japan. Distinguishing between tinkerers and inventors as two forms of household innovation, our results show that household sector inventors tend to think more critically and look forward to developing ideas and being innovative in their careers. We also find that individuals with higher levels of intrinsic learning and career innovation motivation are more likely to spend their spare time tinkering with machines, computers and other devices.

The main contributions of our study are as follows. First, by analyzing how household sector innovation relates to thinking style and learning motivation, we add to the literature about the micro-level determinants of household sector innovation, particularly its psychological and motivational determinants (e.g., Stock et al., 2015, 2016). Second, by bringing together career motivation and household sector innovation, we provide a new perspective on how innovation is linked to occupational choice decisions (Carter, Gartner, Shaver and Gatewood, 2003). Prior occupational choice and career research (see e.g. Blau et al., 1956, for an eFarly overview) has so far neglected household sector innovation and innovative consumer behavior as correlates of career and occupational choice decisions. Finally, as parts of our sample involve respondents from China and Vietnam, our study provides a fresh look at household sector innovation in developing countries. Most prior works on household sector innovation took place in developed Western societies such as the UK (Von Hippel et al., 2012),

Finland (De Jong et al., 2015), Canada (De Jong, 2013) and the US (Ogawa and Pongtanalert, 2011). An Asian emerging market perspective is underrepresented so far. Finally, as household sector innovation can be regarded as a general proxy for an individual's ability to invent and innovate, our study also contributes to literature about the psychological underpinnings of innovation and creativity (Zhang and Bartol, 2010).

The rest of the study is structured as follows: In the next section, we develop our hypotheses based on prior literature. We describe research methods and data in Section 3 and present the findings of the study in Section 4. Section 5 discusses our findings and concludes the study.

2. Theoretical Foundations and Hypothesis Development

2.1. Prior literature on Household Sector Innovation

Users who adapt existing products or invent new products that satisfy their needs are described as user innovators (Von Hippel, 2007). If this innovation takes place at home and for their own private benefit, these user innovators can be referred to as household sector innovators (Ferran, 2000). Household sector innovations can thus be seen as a subset of user innovations.

Several representative national surveys have shown that household sector innovation varies considerably among countries and societies, ranging from 1.5% in South Korea to 9.6% in Russia. The importance of user innovation also varies considerably between industries and product categories and it is prevalent in open-source software (Von Hippel, 2001; Franke and Von Hippel, 2003) and sports equipment (Lüthje, Herstatt and Von Hippel, 2002), but also in scientific instruments (Von Hippel, 1976, 1977) and medical equipment (Füller, Faullant and Matzler, 2010). User innovators in the latter two industries are, however, mostly professional and are unlikely to be household sector innovators.

Concerning micro-level determinants of user innovation, prior research shows that demographic variables such as the level of education, technical background, and gender (e.g. Von Hippel et al., 2012; Kim, 2015) play an important role. User innovation researchers have also started to investigate the psychological determinants of user innovation. Stock et al. (2016) found links between personality traits and successful completion of the fundamental phases of the innovation process. Our study connects to the literature on the psychological underpinnings of user innovation and focuses on thinking style and motivation as two important correlates of household sector innovation. With regard to motivation, we distinguish between learning and career motivation. In the following, we review related literature and develop our hypotheses.

2.2. Thinking Style and Household Sector Innovation

Cognitive Reflection

Sternberg (1998) defines thinking style as the preferred approach by an individual when using cognitive abilities to guide daily tasks, such as understanding and overcoming challenges and difficulties. The dual-process theory of cognition suggests two different ways of thought processes: autonomous processes ("system 1") and memory-dependent processes ("system 2") (Kahneman, 2000). System 1 activates reflexive and intuitive reactions where information is processed quickly without reflection, whereas system 2 requires more effortful thinking and, hence, tends to be slower. This type of thinking is associated with cognitive reflection and has been seen as capacity-limited and rule-based. Rules are applied explicitly to current information; that is, this type of thinking is reflective (Evans and Stanovich, 2013).

Frederick (2005) introduces a three-item cognitive reflection test (CRT) to measure the tendency of activation of the two systems. Each question has an answer that is more intuitive but wrong, and the correct answer needs further reflection to override the "gut" feeling. Therefore, people with higher CRT scores tend to be less reflexive and are more likely to activate effortful thinking with system 2.

A recent dual-process theory proposed by Nijstad, De Dreu, Rietzschel and Baas (2010) suggests that creative thinking is primarily a product of system 2 processes. Empirical evidence also suggests that those who are more motivated or capable of engaging in system 2 processing are more likely to make creative linkages in activities involving the coordination of disparate pieces and the novelty of generated products (Barr, Pennycook, Stolz and Fugelsang, 2015). Since creativity is a necessary condition of innovative activity, we propose the following hypothesis:

Hypothesis 1a: Cognitive reflection is positively related to household sector innovation.

Critical Thinking

From the perspective of cognitive psychology, critical thinking has been defined as receiving both viewpoints of an issue and being open to new disconfirming facts, analyzing thoughtfully, requiring the arguments be supported by proof, deducing and inferring conclusions from the available information (Willingham, 2007). The existing literature has bridged together critical thinking and creativity (Ennis, 1985; Paul and Elder, 2006), as both engage in similar processes (Baum and Newbill, 2010; Halpern, 2013). The process of creativity involves both divergent and convergent phases, where individuals produce a wide range of ideas in the divergent phase and narrow down the number of ideas in the convergent phase. Critical thinking plays an essential role in the convergent phase and

becomes an important factor in the creative process (Spuzic et al., 2016). Therefore, the tendency of critical thinkers to synthesize and analyze the elicited ideas can be viewed as a necessary prerequisite for creative achievement (Baum and Newbill, 2010). Moreover, innovative behavior itself combines the phases of generation, improvement, application, and realization of those creative ideas (Janssen, 2000; Shalley, Zhou, and Oldham, 2004). Hence, we propose the following hypothesis:

Hypothesis 1b: Critical thinking is positively related to household sector innovation.

2.3. Motivations and Household Sector Innovation

Creativity alone is inadequate for developing an innovation (Anderson, De Dreu, and Nijstad, 2004). Persons ought to have a certain amount of internal force that drives them to persist in the face of obstacles when working on innovative projects (Shalley and Gilson, 2004). Both theoretical models and empirical observations correspond to the argument that intrinsic motivation is promotive to creative performance (Amabile, 1983, 1988). Empirical studies on the motives of innovators have also revealed a variety of incentives that consistently relate to user innovation (Raasch and Von Hippel, 2013), such as the enjoyment of developing the innovation (Lakhani and Wolf, 2003; Hienerth, 2006), learning advanced skills from the process of developing the innovation (Bin, 2013; Hienerth, 2006), altruism (Kogut and Metiu, 2001; Lakhani and Von Hippel, 2004) and hedonic and utilitarian motives (Stock et al., 2015).

Intrinsic Learning Motivation

Intrinsic motivation is described as a desire to exert efforts driven by an enthusiasm for and enjoyment of the progress being made (Amabile, 1996). Intrinsic motivation may stimulate creativity through a psychological mechanism based on self-determination: when people are intrinsically motivated, their curiosity and learning willingness improves their cognitive flexibility, openness to sophistication, and tolerance to uncertainty, which broaden their access to insights and potential solutions (Amabile, 1979, 1996). Curiosity can be broadly viewed as a driving force to seize new information and sensory experiences that may elicit exploratory activities (Berlyne, 1978). As such, intrinsic learning motivation can enable persons to channel their desire for knowledge towards producing ideas and encourage them to concentrate on original and innovative ideas that provide the most opportunities for learning and exploration. Therefore, we propose the following hypothesis:

Hypothesis 2a: Intrinsic learning motivation is positively related to household sector innovation.

Career Innovation Motivation

The concept of P-E fit is referred to as the extent of congruence or match between a person (P) and the environment (E) (Kristof, 1996). Among the diverse kinds of P-E fit, scholars have most extensively researched person-organization (P-O) fit at a macro level and person-job (P-J) fit at a micro level. In particular, P-J fit requires the correspondence of knowledge, abilities and expertise (Edwards, 1996). Afsar, Badir and Khan (2015) found that individuals' expectations of how well they fit into their job and organization positively affect their capacity to innovate. Moreover, employees with a better P-E fit tend to be satisfied with their assignments and are intrinsically motivated, while in turn, those who are intrinsically motivated perform their assignments in more innovative ways (De Jong and Den Hartog, 2007).

The entrepreneurship literature also shows that innovation is one of the reasons for choosing jobs (Carter et al., 2003). Household innovators have been shown to have a high level of intrinsic motivation to innovate. Thus, household innovators are more likely to seek a career related to innovation and the development, promotion and implementation of ideas. Based on these theoretical and empirical foundations, we developed the following hypothesis:

Hypothesis 2b: Career innovation motivation is positively related to household sector innovation.

3. Data and Method

3.1. Data Collection and Sampling

This study is based on the analysis of a total of 451 questionnaires. The online survey was administrated at universities in Mainland China, Taiwan, Vietnam, Germany and Japan, as part of the international PANDA study (Preferences, Attitudes, Norms, and Decisions in Asia), where Germany was used as a non-Asian country for comparison. Surveys were advertised at the participating universities[2], so that mostly students and university employees participated. Only completed questionnaires were considered for further analysis, and 354 were excluded from the study due to having extreme outliers or incomplete data. See Table 1 for background characteristics of the respondents. The mean age of the

2. Participating universities were: Trier University (Germany), NCCU (Taiwan), University of Economics HCMC (Vietnam), Hiroshima City University (Japan), and Zhongnan University of Economics and Law (China).

sample was 24.1 years (SD = 6.33), and it ranged from 17 to 57 years old. Of all the respondents, 77% were students and 16% were employed or self-employed. The gender composition of the sample was 55% female (n = 248) and 45% male (n = 203). In terms of the level of education, more than half of the participants held a university degree.

Participants revealed significant gender differences for tinkering (t = -5.32) and invention activities (t = -1.75). In both cases, male respondents were more frequently doing these activities: for tinkering 50% (males) versus 16% (females), for invention activites 67% (males) versus 53% (females). As we have a sample with both students and non-students, the t-test results also demonstrated substantial variations between the two groups in terms of tinkering (t = 2.58), invention activities (t = 1.89), and intrinsic learning motivation (t = 2.34): in general, non-students are more innovative on average than students in both dimensions of household sector innovation. The measurement of these variables is explained in the next subsection.

Table 1. Characteristics of respondents

	Pooled Sample	Taiwan	Mainland China	Vietnam	Germany	Japan	Other countries[a]
	n=451	n=100	n=102	n=72	n=131	n=31	n=15
Gender (%)							
Female	54.70	50.0	61.8	59.5	57.1	35.5	35.3
Male	45.30	50.0	38.2	40.5	42.9	64.5	64.7
Age classes (%)							
<18 years	3.5	4.0	5.9	0.0	3.0	6.5	0.0
19-26 years	75.3	67.0	77.5	87.8	70.7	87.1	70.6
27-32 years	12.3	17.0	3.9	9.5	18.8	0.0	17.6
>32 years	9.0	12.0	12.7	2.7	7.5	6.5	11.8
Mean age(years)	24.1	25.2	23.9	22.8	24.8	21.0	24.9
Highest level of education (%)							
High school degree	33.7	4.0	20.6	36.5	62.4	41.9	35.3
Bachelor's degree	45.5	52.0	61.8	44.6	28.6	45.2	47.1
Master's degree	16.2	37.0	12.7	12.2	6.0	12.9	17.6
Ph.D.	1.1	1.0	2.0	0.0	1.5	0.0	0.0
Other	3.5	6.0	2.9	6.8	1.5	0.0	0.0
Educational background (%)							
Technical/engineering	14.4	16.0	13.7	4.1	22.6	3.2	11.8
Other	85.6	84.0	86.3	95.9	77.4	96.8	88.2
Employment							
Employed/self-employed	16.4	39.0	11.8	18.9	3.8	17.6	6.5
Student/not working	77.7	47.0	79.4	78.4	94.7	82.4	93.5
Others	5.9	14.0	8.8	2.7	1.5	0.0	0.0

a. There were a few respondents living in other European countries.

3.2. Measurement of Variables

All constructs were gauged by multiple questions and they were translated from English into the native language of the respondents. To ensure that all questions were properly translated, a back-translation procedure was applied. All questions can be found in Appendix A.

3.2.1. Dependent Variables

Household sector innovation. We use two dependent variables in our study that capture household sector innovation, namely *tinkering* and *invention activities*. We asked the respondents whether they had made innovations in software products or physical products (De Jong, 2016). To be specific, we asked them: "In your leisure time, do you ever tinker with machines, cars, computers or any other devices, or do you ever program software or apps?" (*tinkering*) and "Do you ever spend your leisure time on inventions or developing new products, applications, or concepts?" (*invention activities*). As such self-reported answers are subjective, an open-ended question followed where the respondent had to describe his or her invention activities, which enables false positives to be validated and eliminated. False positives arise when respondents describe products or activities as innovations which are not based on the definition and thus, should not be classified as user innovations (Flowers, Von Hippel, De Jong, and Sinozic, 2010). To detect them, we manually judged the likelihood that a specific response was indeed innovative. We then coded *each question on a scale from 0 to 2*, where 0 corresponds to "no" (either the respondent answered the question with "no" or the examples given where clearly not innovative, e.g., building an IKEA shelf), 2 corresponds to "yes": clearly innovative actions (examples below), and 1 for an uncertain response that could potentially be innovative.

The dimension *tinkering* was measured as the degree of innovativeness of participants in terms of machines, programming and software products; other physical inventions, such as household crafts and children-related products, were gauged by the dimension *invention activities*.

The answers provided were very diverse, e.g., 'writing small interactive programs in Python', 'developing VR community games', 'customizing bikes' and so on. Some respondents also listed multiple innovations or the development of new products. Of 451 respondents, 174 (38.1%) initially reported that they had modified software, apps or devices, and 161 (35.2%) indicated they had developed hardware products. For validating the reported innovations, one of the independent coders validated innovations according to the descriptions listed by the respondents and generated coding rules. The second independent coder evaluated the innovations based on the coding rules and combined those rules

with answers by the same respondent. The discrepancies between the two coders were discussed and the results were reconciled.

The adjusted sample of household sector innovation contained approximately 70 respondents that named *tinkering* activities and 77 respondents that named *invention activities*, which means that around 16% of all the participants were household innovators (defined as the intersection of both groups); this is comparable to the samples in previous nationally representative surveys. Innovation by individuals in our study covered a wide range of products and activity types, some of the innovations were straightforward, while some were nuanced. Examples of the products developed by the respondents are summarized in Table 2.

Table 2. Summarized examples of household innovations in the sample.

Category		Example
Tinkering	Programming	I have developed an application for people majoring in different subjects which contains puzzles and questions on specific topics that can be helpful in the learning process.
		Software development related to urban rail transit in order to provide passengers with a more precise and user-friendly route.
	Modification and automation	I bought the flight control board and debugged the drone rack.
		I made on my own a remote-control car, combined it with the drone, switched the mode with the remote control, and separated the channels.
Invention activities	Children-related	I build some household stuff and children playgrounds like a tepee in a nearby forest.
	Garden	In our garden, I made a stream for our pond with the available materials.
	Household craft	I made wind chimes with antenna pipes.
	Sports and hobby	I made a baseball collection equipment and my own fitness sandbag.
	Clothing	I designed and sewed some clothes for baby dolls.
	Vehicle	I made an attached wheel on bikes, which can be moved while the bikes are parked closely to each other.
	Medical	I am currently studying ophthalmology-related diseases at an Institute and we need ophthalmic examination instruments, which are quite expensive. So my physics teacher and I assembled the instruments at relatively low cost but with the same effect.
	Pets	Made some home wood ornaments and assembled wooden dog houses.

3.2.2. Independent Variables

Thinking style. Thinking style encompassed *cognitive reflection* and *critical thinking*. An extended version of the CRT was used to measure cognitive reflection. There were five questions in the CRT, and the correct answers were added to calculate the CRT scores. The lowest CRT score of 0 implies that the individual is intuitive, and the highest score of 5 implies that the individual is reflective or analytic; the Cronbach's alpha for *cognitive reflection* was 0.60. *Critical thinking* was measured with a two-term scale. The terms were: "When searching for new information about a certain topic I am typically satisfied to look for a single source." and "When searching for new information I look for both information that confirms and information that contradicts my opinion and then

weigh the arguments against each other for myself." The Cronbach's alpha for *critical thinking* was 0.51.

Learning motivation. The scale of *intrinsic learning motivation* is composed of the following four items: (1) "I enjoy learning new things even if they are not useful for my exams or my work.", (2) "I am happy when I notice that I know things already and do not have to learn them anymore.", (3) "A friend is starting a new hobby and you think about joining your friend since it seems to be a lot of fun. However, you will have to learn a lot to do it well. How likely would it be that you start this hobby with your friend?", and (4) "One of your best friends is planning a language vacation and asks you to join. After seeing some information about the vacation, it seems very appealing to you. However, you will have to learn a lot to do it well. How likely would it be that you go on this vacation with your friend?". The response scale ranged from 1 (Strongly disagree) to 6 (Strongly agree). Internal consistency of *intrinsic learning motivation* as determined by Cronbach's alpha was 0.58.

Career motivation. To measure career motivation, the participants completed an 18-item self-report questionnaire where they were asked to rate to how much they agreed with each statement using a seven-point scale. The scale ranged from 1 (Very Unimportant) to 7 (Very Important). Before testing the hypotheses, we conducted preliminary analyses to control the dimensionality and reliability of the career motivation dimension. Principal component analysis (PCA) was applied to control the dimensionality. The first step was to validate the results of the factor analysis by testing the correlation table determinant, the Kaiser–Meyer–Olkin (KMO) measure of sampling adequacy and Bartlett's significance test, where the KMO should be greater than 0.70, a value less than 0.50 is inadequate (Leech, Barrett and Morgan, 2014). Statistics indicated that all the items measured were highly correlated, providing a reasonable basis for factor analysis (KMO = 0.87, Bartlett's test of sphericity $p < 0.00$). The second step was to take a glance at the scree plot of the PCA to find out the optimal number of components. The analysis suggested the extraction of five factors for the career motivation scale, which explained 77% of the sample variance. Table 3 displays the loadings of each item, the explained variance and the Cronbach's alpha of each factor. Factor 1, labelled 'Benefits', gauges the degree to which participants pursue a career for financial needs and professional accomplishments. Factor 2, labelled 'Self-Fulfilment', measures the extent to which participants achieve personal goals. Factor 3, labelled 'Innovation Motivation', evaluates the degree to which participants look forward to developing ideas in an innovative job. Factor 4, labelled 'Family Business', estimates the extent to which participants have family business goals or continue their traditional family work. Factor 5, labelled 'Social and Environmental Responsibility', assesses the extent to which participants regard their career as following a social or environmental mission. The overall reliability of the career motivation scale as valued by Cronbach's alpha was 0.89 (above 0.70), indicating good reliability and internal consistency (Nunnally, 1978).

Table 3. Career motivation scale principal components analysis results

	Mean	SD	Factor Loading	% of Variance Explained	Cronbach's Alpha
Factor 1: Benefits					
Earn a larger personal income	5.82	0.06	0.86	41.44	0.84
Financial security	6.00	0.06	0.84		
Get greater flexibility for personal life	5.85	0.06	0.65		
Gain a higher position for myself	5.19	0.07	0.59		
Factor 2: Self-Fulfilment					
Grow and learn as a person	6.01	0.06	0.81	12.29	0.84
Realize my own dream	5.82	0.06	0.81		
Challenge myself	5.40	0.06	0.77		
Factor 3: Innovation Motivation					
Develop an idea for a product	4.68	0.08	0.83	9.47	0.85
Be innovative, at the forefront of technology	4.93	0.07	0.72		
Exploit a specific business opportunity	4.92	0.07	0.70		
Factor 4: Family Business					
Continue a family tradition	3.25	0.08	0.87	7.21	0.75
Build business children can inherit	3.68	0.08	0.83		
Follow example of a person I admire	4.18	0.08	0.56		
Factor 5: Social and Environmental Responsibility					
Follow a social mission	4.78	0.07	0.84	4.84	0.74
Follow an environmental mission	5.17	0.07	0.83		
Overall				**76.55**	**0.89**

3.2.3. Control Variables

We controlled for contextual and demographic factors that may affect household sector innovation. Evidence from national surveys identified gender and technical background as significantly related to household innovators (e.g., Von Hippel et al., 2012; Kim, 2015). Technical background was captured by a dummy variable, indicating whether the respondent has a professional background in the field of technology, engineering, computer or natural sciences. Moreover, previous studies found that the *Big Five* personality traits are also linked to the successful accomplishment of the consumer innovation process (Stock et al., 2016). Therefore, we included 10 items to measure the *Big Five* personality traits (Costa and McCrae, 1992), namely extraversion, conscientiousness, agreeableness, openness to experience and neuroticism. Each subscale contains two items rated from 1 (Strongly disagree) to 5 (Strongly agree). Furthermore, cultural differences were captured by a set of country dummy variable as covariates in the analysis.

Full descriptive statistics and correlations between all model variables can be found in Table 6 in the next section.

4. Findings

Table 4. Ordered logistic regression with tinkering as dependent variable

	Model 1		Model 2		Model 3		Model 4	
Cognitive reflection (H1a)			.01	(.12)			-.01	(.12)
Critical thinking (H1b)			.27	(.19)			.20	(.20)
Intrinsic learning motivation (H2a)					.67	(.28) **	.63	(.29) **
Career innovation motivation (H2b)					.31	(.15) **	.31	(.15) **
Control variables								
Age	.02	(.03)	.02	(.03)	.03	(.03)	.03	(.03)
Gender (Male = 1)	1.37	(.32) ***	1.37	(.32) ***	1.38	(.31) ***	1.39	(.32) ***
Student	-.33	(.48)	-.34	(.48)	-.21	(.51)	-.23	(.51)
Education attainment	.17	(.15)	.18	(.15)	.20	(.16)	.21	(.16)
Technical background	.46	(.37)	.49	(.37)	.37	(.38)	.40	(.38)
Extraversion	.03	(.07)	.03	(.08)	-.01	(.08)	-.01	(.08)
Agreeableness	.06	(.10)	.06	(.10)	.05	(.10)	.05	(.10)
Conscientiousness	.10	(.10)	.09	(.11)	.10	(.10)	.10	(.10)
Neuroticism	.10	(.09)	.11	(.09)	.13	(.09)	.13	(.09)
Openness	-.07	(.08)	-.08	(.08)	-.12	(.08)	-.13	(.08)
Benefits	.03	(.13)	.02	(.13)	.04	(.14)	.03	(.14)
Self-fulfilment	.05	(.16)	.02	(.16)	-.04	(.17)	-.05	(.17)
Family business	-.12	(.16)	-.10	(.16)	-.04	(.16)	-.03	(.16)
Social and environmental responsibility	-.15	(.13)	-.16	(.13)	-.18	(.14)	-.18	(.14)
Taiwan	-.15	(.59)	-.34	(.61)	-.10	(.58)	-.25	(.59)
China	-.32	(.58)	-.54	(.61)	-.42	(.57)	-.59	(.61)
Vietnam	-.24	(.58)	-.49	(.63)	-.68	(.61)	-.86	(.65)
Germany	-.48	(.52)	-.67	(.54)	-.25	(.53)	-.41	(.56)
Japan	-.27	(.71)	-.34	(.73)	-.37	(.68)	-.44	(.71)
N	451		451		451		451	
Pseudo R^2	.10		.10		.12		.12	

Notes: Robust standard errors are in parentheses.
**** p<0.01, ** p<0.05, * p<0.1*

Table 5. Ordered logistic regression with *invention activities* as dependent variable

	Model 1		Model 2		Model 3		Model 4	
Cognitive reflection (H1a)			-.02	(.08)			-.01	(.08)
Critical thinking (H1b)			.30	(.14)**			.28	(.14)**
Intrinsic learning motivation (H2a)					.19	(.23)	.14	(.23)
Career innovation motivation (H2b)					.37	(.11)***	.37	(.11)***
Control variables								
Age	.04	(.02)**	.04	(.02)**	.04	(.02)**	.04	(.02)**
Gender (Male = 1)	.28	(.22)	.29	(.22)	.28	(.22)	.29	(.22)
Student	-.11	(.33)	-.13	(.34)	-.17	(.35)	-.20	(.35)
Education attainment	-.03	(.13)	-.02	(.13)	-.05	(.13)	-.04	(.13)
Technical background	.74	(.29)***	.78	(.28)***	.63	(.29)**	.67	(.28)**
Extraversion	.17	(.06)***	.17	(.06)***	.15	(.06)**	.15	(.06)***
Agreeableness	.11	(.07)	.11	(.07)	.11	(.07)	.11	(.07)
Conscientiousness	.03	(.07)	.02	(.07)	.03	(.07)	.02	(.07)
Neuroticism	.04	(.06)	.05	(.06)	.06	(.06)	.06	(.06)
Openness	.06	(.06)	.05	(.06)	.03	(.06)	.02	(.06)
Benefits	-.01	(.11)	.00	(.11)	.00	(.12)	.00	(.12)
Self-fulfilment	.13	(.12)	.09	(.12)	.11	(.13)	.08	(.13)
Family business	-.04	(.11)	-.02	(.11)	.03	(.12)	.05	(.12)
Social and environmental responsibility	.06	(.10)	.05	(.11)	.06	(.11)	.06	(.11)
Taiwan	.35	(.50)	.11	(.53)	.43	(.50)	.21	(.52)
China	.40	(.47)	.15	(.50)	.37	(.48)	.14	(.50)
Vietnam	.65	(.50)	.37	(.54)	.44	(.53)	.20	(.56)
Germany	-.20	(.47)	-.43	(.50)	.03	(.48)	-.19	(.50)
Japan	.78	(.69)	.66	(.69)	.77	(.67)	.65	(.67)
N	451		451		451		451	
Pseudo R^2	.05		.05		.06		.07	

Notes: Robust standard errors are in parentheses.
*** p<0.01, ** p<0.05, * p<0.1

To get a better understanding of how psychological, motivational, and demographic characteristics influence different types of innovation in the household sector, we run ordered logistic regressions with tinkering and invention activities as dependent variables (Tables 4 and 5, respectively).

Hypotheses 1a and 1b state that the thinking style will positively influence the level of household sector innovation through *Cognitive reflection* (Hypothesis 1a) and *Critical thinking* (Hypothesis 1b) respectively. Tables 4 and 5 show that *Cognitive reflection* is neither related to tinkering nor to invention activities. Hypothesis 1a is thus not supported. Models 2 and 4 in Table 5 show that *Critical thinking* is significantly positively correlated with invention activities ($p < 0.05$). However, *Critical thinking* is not related to tinkering (Table 4). Hypothesis 1b is partly supported.

The second set of hypotheses stated that individuals with higher levels of *intrinsic learning motivation* (Hypothesis 2a) and *career innovation motivation* (Hypothesis 2b) would demonstrate higher levels of household innovation. Models 3 and 4 in Table 4 and 5 show that individuals driven by career innovation motivation are more likely to innovate in the household sector (tinkering $p < 0.05$; invention activities $p < 0.01$), thereby fully supporting hypothesis 2b. We only find a significant positive relationship between *Intrinsic learning motivation* and tinkering ($p < 0.05$), as shown in Table 4, but not with invention activities (Table 5). Hypothesis 2a is thus partly supported.

When demographic variables are considered, household sector tinkerers and inventors demonstrate similarity to the innovators in previous national surveys. The evidence from previous national household sector research indicate that males as well as consumers with a technical background, are more likely to innovate (e.g. Von Hippel et al., 2012; Kim, 2015). Studies also show that extraversion as a personal trait significantly correlates with consumer innovation success (e.g. Stock et al., 2016). Table 4 shows a significant gender difference for Tinkering, consistent with the previous studies which suggest that males are more likely to innovate than females, especially in machine-related or technology sectors. Importantly, with respect to Invention activities, we do not find a significant gender difference (Table 5). Gender is thus significantly related to tinkering but not to invention activity. Conversely, a technical background is significantly and positively related to invention activity (Table 5) but not to tinkering (Table 4). The same pattern of results was also found for *Extraversion*.

In short, we find that household sector inventors tend to think more critically and look forward to developing ideas and being innovative in their careers. They are also more often extravert and have a technical background. Moreover, males and individuals with higher levels of both intrinsic learning and career motivation are more likely to spend their spare time on tinkering with machines, computers and other devices.

Table 6 summarizes the descriptive statistics and correlations among the variables. The correlation matrix shows that the absolute values of the correlations between the explanatory variables were basically modest ($r < 0.5$). Furthermore, the mean-variance inflation factor (VIF) was 2.26 and the VIF values of all the variables were below ten; therefore, it rules out any concerns about multicollinearity.

5. Discussion and Conclusion

The present paper studied household sector innovations, as a subset of user innovations that specifically take place at home and for the innovator's own private benefit. In particular, we investigated the individual-level determinants of household sector innovation while distinguishing between two forms of household sector innovation: tinkering and invention activities. We took a micro

perspective, examining individuals' perceptions as well as cognitive factors and motives that relate to the innovation activities. Based on a sample of 451 individuals in our survey, we found that household sector *inventors* tend to think more critically and look forward to developing ideas and being innovative in their careers. This career motivation perspective is also found as a determining factor for *tinkering* activities. In addition, tinkering activities are also positively associated with an intrinsic learning motivation.

5.1. Implications for Practice

The current findings show that household sector innovation is linked to a psychological mechanism. This is in line with innovation literature theorization (Amabile, 1983; Shalley et al., 2004; Anderson, Potonik, and Zhou, 2014). Individuals who are better in critical thinking tend to be more open-minded and accept diverse viewpoints more easily. They are not only keen on new information and seek out authentic and objective knowledge, but also perform a problem-solving process in an organized and thoughtful way (Aizikovitsh-Udi and Cheng, 2015; Kirmizi, Saygi and Yurdakal, 2015). However, critical thinking might be particularly challenging for students from Asian cultures where conformity is a widely accepted social norm and challenging the authorities is less encouraged (Davies, 2013; Shaheen, 2016). Little evidence, however, shows that Asian students have fundamentally different dispositions when it comes to learning and critical thinking. Therefore, in order to encourage the development of innovations, it seems likely that Eastern countries should emphasize critical thinking and problem-solving skills in their education system.

Household sector innovators do not behave economically but endeavor to address their problems; therefore, they are mostly intrinsically motivated. Our findings are in line with those of previous work that affirm the relevance of intrinsic motivations as drivers of innovators in the household sector (Lakhani and Von Hippel, 2004; Stock et al., 2015). Prior work, however, has not sufficiently investigated all facets of innovators' motivations to innovate. This research thus extends previous studies by empirically examining the importance of intrinsic learning motivation and vocational choice in developing a relevant framework of proactive household sector innovation behaviors. Moreover, our findings provide an understanding of the connection between person-environment fit and innovation activities from a different perspective, as well as offering fresh insights for researching the effect mechanism of person-environment fit on innovation behavior. In practice, recruiters could assess the fit between candidates' task and role preferences, especially when they are looking for candidates for innovation projects. Assessments on intrinsic learning motivation and career requirements can also be taken into account for entrepreneurship programs in universities or relevant departments (Elert, Sjöö and Wennberg, 2020).

Another contribution of this research pertains to exploring individual innovation across countries. Cultural values (Hofstede, 2001; Schwartz, 1999) likely reflect how innovation is enacted and cultivated in various countries. Previous research has shown the scale and scope of household innovation in developed countries (e.g. De Jong et al., 2015; Ogawa and Pongtanalert, 2011; Kim, 2015; Von Hippel et al., 2012). Our results enrich the growing body of research on exploring cross-country variation in household sector innovation by focusing on developing countries where many innovations were initially produced in households but are absent from official statistics (De Jong, 2016).

Men innovate more in general; however, our results paint a somewhat different portrait of female inventors in the countries included in our sample, including Vietnam and Japan. We discovered and documented that in the case of invention activities in the household sector, innovations generated by males and females are not substantially different (see Table 5 where variable *Gender* is not significant). We speculate that despite the international liberalizing of gender ideology and the fact that cross-nationally, women also expanded their engagement in paid labor on a global scale, women still maintain the responsibility for the majority of household and childcare responsibilities (Diefenbach, 2002; Okamuro and Ikeuchi, 2017). This makes women the majority of innovators relating to the childcare and family health management category (Von Hippel and Cann, 2020). Our results therefore provide evidence that gender roles determine the extent of knowledge, skills, and experience regarding a specific category of innovation across countries, namely household sector invention activity. In practice, policymakers could encourage women to involve in innovative practices. Financing schemes and other grants could also encourage and expand the contribution of female innovators to economic growth. It may also be helpful for women to have communities that allow them to share and communicate their household sector innovations.

5.2. Limitations and Suggestions for Further Research

The results obtained from this study have several limitations and suggest opportunities for further research. First, because several questionnaire items in our survey are self-reported, the results may be considered subjective. For example, the self-assessed level of critical thinking is relatively high, which could be driven by social desirability or inflated self-appraisal. However, due to evidence of construct validity within the factors, the possibility of self-reporting bias does not appear to have an impact on the findings of this study. Future research could address this concern by applying objective metrics and gathering household innovation activities not just from the individuals themselves but also from other sources. Second, concerning the vocational choice factor, we cannot entirely rule out the possibility of reverse causality due to the cross-sectional

research design (Rindfleisch, Malter, Ganesan and Moorman, 2008). Correspondingly, we propose that a longitudinal analysis can be carried out in the future, enabling identification of innovators' career preferences and the aggregation of career-related resources before and during the developing process of household sector innovations, which could further support the validation of causal effects and contribute to methodological advancement in this area. Third, we separated the dependent variable of household innovation into tinkering and invention activities; by unwarping it into its sub-dimensions, we were able to explore a more fine-grained understanding of the motivations associated with novelty and usefulness. However, we did not differentiate the phases of innovative activity (e.g., idea generation, implementation, and diffusion). This restricts the current research given that psychological determinants have differential impacts on different phases of innovation. Future studies may expand on the nature of innovative activities to investigate further aspects of household sector innovation.

Table 6: Reliabilities and Correlations among Variables

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Mean	.45	24.14	.14	1.95	.32	.59	3.93	4.05	3.20	.00	5.93	6.35	6.03	6.12	7.13	-	-	-	-
S.D	.50	6.36	.35	.93	.72	.76	1.25	.73	.54	1.00	1.81	1.56	1.51	1.79	1.86	-	-	-	-
1. Male	(-)																		
2. Age	.07	(-)																	
3. Technical background	.23***	.07	(-)																
4. Education attainment	.10*	.28***	-.06	(-)															
5. Tinkering	.24***	.12***	.12**	.13***	(-)														
6. Invention activities	.10*	.14***	.12**	.06	.45***	(-)													
7. Cognitive reflection	.07	-.07	.15***	.02	.02	-.01	(.60)												
8. Critical thinking	-.02	.09*	-.04	.00	.04	.11**	.04	(.51)											
9. Intrinsic learning motivation	-.03	-.01	-.08	.04	.06	.12***	.07	.19***	(.58)										
10. Career innovation motivation	.07	-.05	.07	.04	.10**	.21***	.01	.04	.15***	(-)									
11. Extraversion	-.02	.05	-.06	.01	-.01	.14***	-.07	.03	.06	.08	(.57)								
12. Agreeableness	-.10**	-.06	.00	.11**	.01	.07	.06	.00	.10**	.08*	.03	(.57)							
13. Conscientiousness	.02	.16***	-.02	.03	.04	.03	-.08*	.13***	.01	-.03	.14***	-.02	(.46)						
14. Neuroticism	-.23***	-.11**	-.06	-.05	-.02	-.05	-.06	-.09*	-.06	-.13***	-.19***	-.15***	-.13***	(.48)					
15. Openness to experience	-.02	-.06	-.02	-.06	-.06	.07	.02	.16***	.20***	.09*	.11**	-.03	.09*	.03	(.43)				
16. Benefits	-.10**	-.01	-.07	.08	-.01	-.01	.06	-.01	.05	.00	-.07	.04	-.10**	.07	-.06	(.84)			
17. Self-fulfilment	.06	-.03	-.05	-.07	.00	.05	-.05	.18***	.20***	.00	.07	-.03	.18***	-.11**	.24***	-	(.84)		
18. Family business	.10**	.09*	-.02	.15***	.01	.06	-.03	-.04	.04	.00	.10**	.10**	-.02	-.07	-.06	-	-	(.75)	
19. Social and environmental responsibility	-.16***	.08	-.09*	.00	-.07	.05	.09*	.11**	.19***	0	.12**	.05	.10**	.09*	.10 **	-	-	-	(.74)

Notes: S.D. = standard deviation; diagonal elements in parentheses are values of Cronbach's alpha. *** p<0.01, ** p<0.05, * p<0.1.

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Appendix A: Measurement		
Variable Name	Measure	Construction
Cognitive reflection	1. A pen and an eraser cost 1.10 € in total. The pen costs 1.00€ more than the eraser. How much does the eraser cost? __ cents.	Sum of the correct answers
	2. If it takes 5 machines 5 minutes to make 5 widgets, how long would it take 100 machines to make 100 widgets? 3. In a lake, there is a patch of lily pads. Every day, the patch doubles in size. If it takes 48 days for the patch to cover the entire lake, how long would it take for the patch to cover half of the lake? 4. If you are running a race and you pass the person in second place, what place are you in? 5. Laura is 10 years old. Her father has three daughters. The first two are named April and May. What is the third daughter's name? (Versions varied slightly according to local languages.)	
Critical thinking	How much do you agree or disagree with these statements? (in both cases: 1 = strongly disagree...5 = strongly agree)	Critical Thinking = (CTS3+CTS1_reversed)/2
	CTS1 When searching for new information about a certain topic I am typically satisfied to look for a single source.	
	CTS3 When searching for new information I look for both information that confirms and information that contradicts my opinion and then weigh the arguments against each other for myself.	
Intrinsic learning motivation	How much do you agree or disagree with these statements?	Learning willingness1=(LA1+LA3)/2
	(in all cases: 1 = strongly disagree...6 = strongly agree) LA1 I enjoy learning new things even if they are not useful for my exams or my work.	Learning willingness2 =(LB1+LB2)/2
	LA3 I am happy when I notice that I know things already and do not have to learn them anymore.	Intrinsic learning
	LB1 A friend is starting a new hobby and you think about joining your friend since it seems to be a lot of fun. However, you will have to learn a lot to do it well. How likely would it be that you start this hobby with your friend?	motivation = (Learning willingness 1 + Learning willingness 2)/2
	LB2 One of your best friends is planning a language vacation and asks you to join. After seeing some information about the vacation, it seems very appealing to you. However, you will have to learn a lot to do it well. How likely would it be that you go on this vacation with your friend?	
Career innovation motivation	Refers to Table 3	Principal Component Analysis
	How important are the following motives for your future work and career path?	
	(1 = very unimportant...7 = very important)	
	1. Challenge myself	
	2. Realize my own dream	
	3. Grow and learn as a person	
	4. Earn a larger personal income	
	5. Financial security	
	6. Build business children can inherit	
	7. Continue a family tradition	
	8. Follow example of a person I admire	
	9. Be innovative, at the forefront of technology	
	10. Develop an idea for a product	
	11. Achieve something, get recognition	
	12. Gain a higher position for myself	

	13. Get greater flexibility for personal life	
	14. Be my own boss	
	15. Realize my own dream	
	16. Exploit a specific business opportunity that I recognized	
	17. Follow a social mission	
	18. Follow an environmental mission	
Control variables		
Gender	0 = female; 1 = male	
Age	in years	
Student	0 = no; 1 = yes	
Education attainment	1 = High school; 2 = Bachelor's Degree; 3 = Master's degree; 4	
	= PhD; 5 = others	
Technical background	0 = no; 1 = yes	
	(1 = strongly disagree . . . 5 = strongly agree)	
Extraversion	I see myself as someone who … is reserved. R	
Agreeableness	… is outgoing, sociable. … is generally trusting. … tends to find fault with others. R	
Conscientiousness	… tends to be lazy. R … does a thorough job.	
Neuroticism	… is relaxed, handles stress well. R … gets nervous easily.	
Openness to experience	… has few artistic interests. R … has an active imagination.	
Benefits	Refers to Table 3	
Self-fulfilment	Refers to Table 3	
Innovation Motivation	Refers to Table 3	
Family business	Refers to Table 3	
Social and environmental responsibility	Refers to Table 3	
Dependent variables		
Tinkering	In your leisure time, do you ever tinker with machines, cars, computers, or any other devices, or do you ever program software or apps?	0 = no; 1 = uncertain responses; 2 = yes
Invention activities	Do you ever spend your leisure time on inventions or developing new products, applications, or concepts? Examples could include:	0 = no; 1 = uncertain responses; 2 = yes
	a. Creating household fixtures and furnishing,	
	b. Transport or vehicle related products,	
	c. Utensils, molds, gardening tools, mechanical or electrical C5,	
	d. Sports, hobby, and entertainment products, such as Sports devices or games,	
	e. Children and education-related products, such as toys and tutorials,	
	f. Help, care or medical-related products.	

Note: R = reversed coded item.