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The rich or the poor? Personal resources, do-it-yourself, and innovation in the household sector

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ABSTRACT

Household sector innovation is significant in scale and scope. Thus far, it has been studied in isolation and with mixed evidence regarding the role of personal resources (consumers' income and discretionary time). We recognize that household sector innovation is embedded in the broader phenomenon of do-it-yourself (DIY) by consumers, as the literature reveals conceptual similarities, parallel motivations, and antecedents. The main distinction is that, whereas DIY goods may replicate existing products, household sector innovation is restricted to goods embodying a novel function. We explore if studying household sector innovation and DIY in an integrated framework helps to resolve previous inconsistent evidence on the role of personal resources. Based on a neoclassical model in which agents optimize their time allocation, we hypothesize that income and discretionary time positively relate to their DIY output, but—given that agents develop DIY goods—we hypothesize that income negatively relates to innovation. For discretionary time, we formulate a research question regarding its effect on innovation which we answer empirically. Our findings suggest that consumers with more personal resources derive more process benefits from DIY but that these benefits crowd out individuals' focus on the function of their objects, hence, the likelihood of developing innovations. Survey data from the United Arab Emirates (n = 2728) confirm our suppositions, showing that the relationship between personal resources and household sector innovation is more refined than suggested by previous studies.

1. Introduction

Household sector (HHS) innovation is the development by consumers of functionally novel products, processes, or other applications in their discretionary time without payment (von Hippel, 2017). Across a range of countries, the incidence of HHS innovation in consumer populations is generally found to be 4 to 6 %, representing millions of consumers who spend billions of dollars developing HHS innovations (de Jong, 2016; von Hippel, 2017). Their creations, more often than the innovations by firms, enable new functions rather than incremental improvements (Hienerth et al., 2014; Riggs and Von Hippel, 1994). An example of a groundbreaking technology resulting from HHS innovation is the first aircraft (Meyer, 2012). Thereby, HHS innovation is a source of venture creation at the edge of new industry emergence (Shah and Tripsas, 2007). HHS innovation is expected to rise because the production of immaterial goods (e.g., software)—which is more accessible to the public—gains importance as compared to material production (e.g., automobiles) (Ritzer et al., 2012). Furthermore, consumers increasingly have the competencies and tools to innovate for themselves (Fox, 2014). So far, researchers have explained HHS innovation by looking at antecedents such as gender or education, but this line of research is still in its infancy.

In a recent special issue in Research Policy, de Jong et al. (2021) recognized that HHS innovation is embedded in more general consumer behaviors aimed at self-production, like do-it-yourself (DIY), and recommended new research that accounts for this embeddedness. In our study, we follow up on this advice. DIY is done by individuals creating goods they think of themselves (Fox, 2014): to address personal needs, enjoy the process of design and home production, and/or express themselves (Xie et al., 2008). Like HHS innovation, DIY requires creativity, judgment, and skill as individuals are both engaged with designing and producing goods (Watson and Shove, 2008). With the availability of today's technologies, DIY activities can include traditional goods like furniture (Wolf and McQuitty, 2011) and complex products based on computer-aided design (Rajan, 2021; Rayna and Striukova, 2021). Following de Jong et al. (2021), the main difference between DIY and HHS innovation is the functional novelty of its outcomes—HHS innovations, by definition, enable novel functions (von Hippel, 2017),

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while DIY objects may be homebuilt versions of existing goods (e.g., Fox, 2014; Williams, 2004; Wolf and McQuitty, 2011).

Acknowledging the embeddedness of HHS innovation in DIY helps us to shed new light on the antecedents of HHS innovation. In particular, we focus on the role of personal resources (income and discretionary time) and answer the question of whether resource-rich or resource-poor people are more likely to develop DIY goods and HHS innovations. Previous evidence regarding the role of income has been mixed. Gupta (2013) and Praceus and Herstatt (2017) found qualitative evidence that poor individuals are more likely to innovate as they satisfy their personal needs in a context where alternatives are lacking. In contrast, Chen et al. (2020) found a positive correlation between income and HHS innovation. They argued that, at higher levels of income, individuals are better able to finance innovation tools and reach self-actualization by working on innovative projects. Concerning discretionary time, no previous studies about its association with HHS innovation have been done.

In this paper, we first explain that DIY and HHS innovation are truly overlapping concepts and conceptualize a framework in which HHS innovation is embedded in DIY. Next, we construct a neoclassical time allocation model to explore how personal resources impact DIY and HHS innovation in an integrated framework. Based on our model, we hypothesize that resource-rich people are more likely to develop DIY goods. An essential driver of this effect is that the rich derive more process benefits (e.g., enjoyment, self-expression) from DIY than the poor, who develop DIY goods predominantly out of economic consideration. We also anticipate that, given that people develop DIY goods, resource-poor people are more likely to develop goods with novel functions, hence, to be HHS innovators. For the poor, whose resource constraints may force them to find creative solutions for lacking market alternatives, missing functionalities are key to engaging in DIY—increasing the likelihood of coming up with truly novel solutions. We find confirmation for our hypotheses in a sample of 2728 citizens of the United Arab Emirates.

Our contribution to the existing literature is threefold. First, the parallels we find between HHS innovation and DIY bridge two previously disconnected strands of literature. Integrating these strands of literature is paramount to a better understanding of HHS innovation in future work. Second, we find an empirical explanation for conflicting evidence about the role of personal resources in HHS innovation emergence, as reported in previous studies. We find that income and discretionary time are positively associated with DIY, but—given that DIY is observed—people with less income and discretionary time are more likely to develop functionally novel goods. Third, we connect HHS innovation to economic theory by applying a modified version of Becker's (1965) time allocation model. This provides a more in-depth account of the underlying mechanisms driving the effects of personal resources on DIY and HHS innovation than previous work (e.g., Chen et al., 2020) has attempted. We show that process benefits may be a key mechanism in this respect and can provide an (economic) rationale for people's decision to increase their DIY engagement when their income increases—even when this means an increase in their opportunity costs of not working.

2. Literature review

2.1. Household sector innovation

HHS innovations are important for economic and societal welfare. As HHS innovators are more likely than producers to innovate at the leading edge of markets—where demand is still too uncertain for established firms—they have a pioneering role in steering technological change (Baldwin et al., 2006; Hienerth et al., 2014). Societal welfare increases when HHS innovations diffuse. This can happen either through new venture creation (Shah and Tripsas, 2007) or when incumbent producers adopt the innovations by consumers. The latter occurred, e.g., in kitesurfing (von Hippel and Kaulartz, 2021). HHS innovation can give rise to competition, such as in the case of Linux versus Windows, but it can also give rise to goods that complement existing commercial offerings.

Consequently, both consumers and producers can benefit from HHS innovation. An example where this is observed is the gaming industry (Gambardella et al., 2017). Incumbent producers are, therefore, encouraged to facilitate and leverage knowledge developed by innovating householders (Gambardella et al., 2017; von Hippel, 2017).

Its high societal relevance has inspired scholars to study the antecedents of HHS innovation. So far, scholars have identified demographic factors such as gender (Fursov et al., 2017; Kim, 2015), competence-related variables such as education and technical work experience (see, e.g., von Hippel et al., 2012), lead-user characteristics (Franke et al., 2006), and personality traits such as openness and conscientiousness (Stock et al., 2016) as predictors of HHS innovation.

2.2. Who innovates: the resource-rich or the poor?

Researchers have also investigated the role of personal resources—in particular, the role of income. But the empirical evidence on its relationship with HHS innovation is mixed.

Chen et al. (2020) surveyed Chinese citizens and found a positive association between citizens' level of income and innovation. They suggested two explanations. First, based on Maslow's (1943) hierarchy of needs, Chen et al. (2020) argued that income positively affects people's pursuit of higher-order life goals (e.g., self-actualization) and that developing innovations can be part of such goals. Second, based on planned behavior theory (Ajzen, 1991), the authors argued that income might increase one's perceived behavioral control—i.e., how one perceives one's ability to execute the actions required to deal with prospective situations (Ajzen, 1991; Bandura, 1977, 1982)—which has been shown to enhance consumers' innovation activities (Hau and Kang, 2016). Income helps to secure access to innovation resources like design tools and (paid) assistance to support the innovation process, potentially increasing one's perceived ability.

However, these theoretical explanations do not seem compatible with related studies on HHS innovations developed by those who are deprived of personal resources (Gupta, 2006; Gupta, 2013; Praceus and Herstatt, 2017; Rajan, 2021). Having documented thousands of innovations developed in India, Gupta (2006) recognized high innovation potential in lower-income groups. By strengthening ties between local villagers and the scientific community, Gupta (2006) witnessed an immense amount of local knowledge that, when diffused, led to numerous patents filed in India as well as in the US. Praceus and Herstatt (2017) even found that individuals at the bottom of the pyramid in India were more likely to create new solutions as compared to UK consumers, who focused more on incremental solutions. The mechanism that drives these resource-deprived people to be more innovative seems to be that, in order to benefit from innovation, they need to focus on the distinct function their creations fulfill and not on incremental changes or added luxury—as has also been advocated in the bottom-of-the-pyramid innovation literature (Prahalad and Hart, 2000).

These findings suggest a different interpretation of Maslow's (1943) hierarchy of needs in the context of HHS innovation than the interpretation by Chen et al. (2020). Observations at the bottom of the pyramid in India suggest that people's push for basic needs—innovating for necessity—results in the development of goods that add a novel function (i.e., HHS innovations) rather than the pursuit of self-actualization goals, observed more frequently under people living in high-income areas (Williams, 2008). Furthermore, evaluating the role of planned behavior theory, behavior is not only affected by perceived behavioral control (which might indeed be higher for people with more income) but also by intention—i.e., the motivation to engage in a particular behavior (Ajzen, 1991). Based on the hierarchy of needs (Maslow, 1943), the intention for behavior necessary for securing basic needs is higher than the intention for behavior in pursuit of higher-order needs. As

innovating for necessity is more prominent at the bottom of the pyramid (Rajan, 2021), this creates ambiguity in whether income actually leads to a higher likelihood of HHS innovation when considering both perceived ability and intention as elements of planned behavior theory.

So far, we have only discussed the role of income. In surveys of HHS innovation, citizens' discretionary time has not yet been investigated as an explanatory variable. By definition, HHS innovation requires at least some discretionary time. However, whether and how increases in discretionary time affect innovation is unclear. Agrawal et al. (2018) studied the innovative activities on Kickstarter by a consumer sample (primarily students) in relation to their slack time. They found that the number of projects increased with consumers' slack time but also more dispersion in the quality of the innovative projects. Agrawal et al. (2018), however, did not investigate the dimension of functional novelty when evaluating the projects. Hence, it is unclear what the effect of discretionary time would be in the context of HHS innovation.

In summary, the literature is inconclusive about the association between personal resources and HHS innovation. As we explain hereafter, recognizing that HHS innovation is embedded in the broader concept of DIY helps to explain past incompatible research findings.

2.3. Do-it-yourself

We define DIY as the active design and production by consumers of products, processes, or other applications in their discretionary time without payment. In contrast to HHS innovation, DIY may result in functionally novel goods (Fox, 2014; Mauroner, 2017; Wolf et al., 2020), but not necessarily so (e.g., Williams, 2008; Wolf and McQuitty, 2011). Therefore, HHS innovations can be regarded as a subset of DIY, reflecting goods that enable a novel function.

The nature and scope of DIY have evolved quickly in the past few decades, accelerated by technological progress (Ritzer and Jurgenson, 2010). In essence, DIY is rooted in prosumption (Kotler, 1986; Toffler, 1980)—formally defined by Xie et al. (2008, p. 110) as "value creation activities undertaken by the consumer that result in the production of products they eventually consume and that become their consumption experiences". Futurist Toffler (1980) was early to identify three eras of societal progress (i.e., the agricultural, industrial, and information society) marked by subsequent 'waves' of prosumption: subsistence, industrial, and information-based. Fox (2014) summarized their main characteristics as in Table 1.

The industrial revolution introduced mechanization to manufacturing processes, implying that means of production became more concentrated (Toffler, 1980). Big firms increasingly engaged in production and shaped and satisfied the needs of passive consumers—whose production function was marginalized to rather minimal efforts such as cooking meals or putting together made-to-forecast kits of goods (Fox, 2014; Rayna and Striukova, 2021; Ritzer and Jurgenson, 2010). Thanks to the information revolution, individuals re-gained the possibility to take greater care of their own individualized needs (Dusi, 2018; Toffler and Toffler, 2006). Enabling technologies (such as Web 2.0 and additive manufacturing) have propelled a 'Third Wave' of prosumption (Fox, 2014), in which individuals generate and share digital content online (Ritzer and Jurgenson, 2010) and use these to produce physical goods at home (Belk, 2014; Rayna and Striukova, 2021). The re-emergence of the prosumer can be observed in a plurality of forms, including co-creation (in which consumers have an active role in the consumption/usage of goods, e.g., online videogames where the experience is co-created by the players (Prahalad and Ramaswamy, 2004)), co-production (in which consumers take over parts of the production process from producer firms, e.g., putting together Ikea furniture (Etgar, 2008)), and DIY.

Table 1
Definition of subsistence, industrial, and information-based prosumption.

	Subsistence prosumption	*Industrial prosumption*	*Information-based prosumption*
Definition	People grow what they eat and make what they personally need without regularly making purchases in a marketplace	People buy made-to-forecast kits of goods	People draw upon the read and write functionality of the Internet and digitally-driven design/ manufacture to invent, design, and make goods that they think of themselves
Example	People building their own houses with local resources	IKEA furniture kits	Self-designed 3D printed objects

Source: Fox (2014).

What sets DIY apart is that it requires high, proactive involvement from consumers (Wolf and McQuitty, 2011; Wolf et al., 2020). DIYers apply their skills, knowledge, and judgment to produce goods they design and build themselves (Campbell, 2005; Watson and Shove, 2008). Partly because DIYers now have access to means of production that were formerly restricted to firms, DIY outcomes can compete with (and sometimes even outcompete) commercial offerings (Dellaert, 2019; Rayna and Striukova, 2021) and be a breeding ground for innovation (Wolf et al., 2020).

DIY encompasses a range of creative activities in which consumers develop products, processes, or other applications in their discretionary time. Modern examples are hackers—who reappropriate and redesign objects for other than their original purposes (Williams et al., 2012), and makers—who passionately engage in the production of new objects (Dougherty, 2012). What hacker- and maker-DIYers have in common is that they are both concerned with unique applications of complex technologies (Mauroner, 2017), for example, in 3D printing (Browder et al., 2019). This makes the connection between DIY and innovation more clearly visible (Fox, 2014; Hahn et al., 2016). Yet, 'classical' DIY activities such as home remodeling and furniture design (Collier and Wayment, 2018; Williams, 2004, 2008; Wolf and McQuitty, 2011) also fit our definition of DIY. Hence, we consider both classical and modern appearances of DIY, recognizing that both these different forms can result in functionally novel goods (Fox, 2014; Wolf et al., 2020), which would qualify DIYers as innovators.

Our conceptualization of HHS innovation as embedded in DIY and prosumption is visualized in Fig. 1 below. To summarize, we consider HHS innovations a subset of DIY goods. HHS innovations are distinct from DIY goods by enabling a novel function (de Jong et al., 2021). Subsequently, we consider DIY a specific form of prosumption. Compared to other forms of prosumption (e.g., co-creation or co-production) (cf. Ritzer and Jurgenson, 2010), DIY requires a higher degree of involvement from the consumer (Wolf and McQuitty, 2011; Wolf et al., 2020)—the consumer both actively designs and produces the good (Campbell, 2005; Watson and Shove, 2008).

2.4. Other similarities between DIY and HHS innovation

Beyond their relatedness, as visualized in Fig. 1, the literature on DIY and HHS innovation identified similar trends explaining why the scale and scope of the phenomena have increased. DIY has grown with the emergence of the Internet, the availability of low-cost design tools (Fox, 2014; Rayna and Striukova, 2021; Ritzer and Jurgenson, 2010), and the shift from material to immaterial production (Ritzer et al., 2012). In these circumstances, an increasing number of people around the globe engage in DIY (Anderson, 2012; Hatch, 2013). Innovation scholars identified similar trends for HHS innovation: its importance increased during the past twenty years with the Internet, low-cost design tools, improved education, and improved connectedness of individuals (e.g., Chen et al., 2020; Stock et al., 2016; von Hippel, 2017; von Hippel et al., 2012).

Next, the reported motives for individuals to develop DIY goods and HHS innovations are highly similar. People generally develop HHS

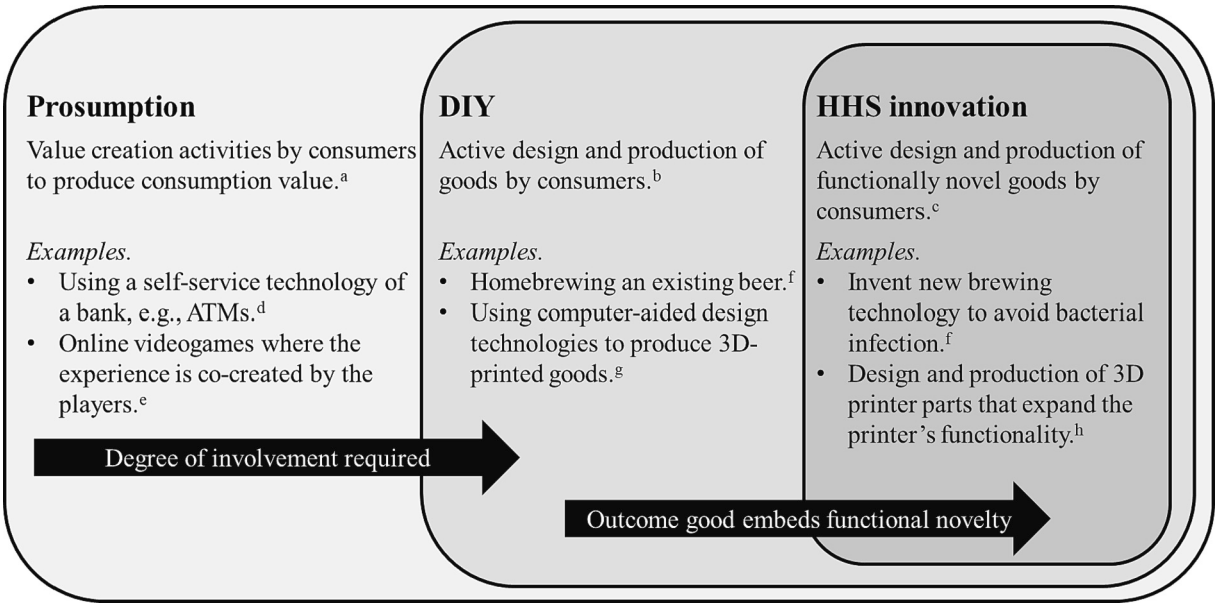

Fig. 1. Conceptual framework of HHS innovation embedded in DIY and prosumption.
Sources: [a]Xie et al. (2008), [b]Watson and Shove (2008), [c]von Hippel (2017), [d]Dusi (2018), [e]Prahalad and Ramaswamy (2004), [f]Wolf et al. (2020), [g]Browder et al. (2019), [h]Mulhuijzen and de Jong (2022).

innovations for personal use-value (von Hippel, 2005) and/or for process benefits such as fun, self-expression, and learning (Raasch and von Hippel, 2013). Similar motives apply to DIY (Xie et al., 2008), as seen in Table 2. Both strands of the literature rarely encountered commercial benefits as an essential motivator.

The DIY literature has elaborated on motives in more detail. Yet, in studies of narrower forms of HHS innovation, we can also identify accounts of community interest and self-fulfillment motivations—for example, in studies of open-source software (Lakhani and Wolf, 2005) and online knowledge-sharing platforms (de Jong and Lindsen, 2021).

Acknowledging their high resemblance and the embeddedness of HHS innovation in DIY, we study the role of personal resources through a theoretical model that integrates the concepts of DIY and HHS innovation.

Table 2
Motives for do-it-yourself and household sector innovation.

Motive	Do-it-yourself	Household sector innovation
Use/consumption benefits	Use-value of design[a,b,c,d]	Solution to a personal need[e,f]
	Lack of (good) alternatives[a,b,c,d]	
	To tailor a design to personal needs[a,b,c]	
Process benefits	To learn[b,h]	To learn or develop skills[e,f]
	For fun and enjoyment[a,b,c]	For fun and enjoyment[e,f]
	To help others[c]	To help others[e,f]
	To connect with a community[c,g,h]	
	Self-fulfillment[c]	
	Sense of control[c]	
Commercial benefits	For employment opportunities[h]	To earn money[e,f]

Sources: [a]Williams (2004), [b]Williams (2008), [c]Wolf and McQuitty (2011), [d]Wolf and McQuitty (2013), [e]de Jong et al. (2015), [f]Chen et al. (2020), [g]Collier and Wayment (2018), and [h]Kuznetsov and Paulos (2010).

3. Hypotheses

To develop an in-depth rationale for the relationships between personal resources, DIY, and HHS innovation, we developed a theoretical model in which agents maximize utility over their time invested in working on the labor market, producing DIY goods, and leisure, and—given that they produce DIY goods—develop HHS innovations.

3.1. Theoretical model

We draw on Becker's (1965) neoclassical model developed to explain the time allocation of households over labor market participation, leisure time consumption, and home production. The premise of this model is that "households are producers as well as consumers" (Becker, 1965, p. 516). We adopt the fundamentals of Becker's model to explain the trade-off between agents' labor market participation and leisure time consumption but add engagement in DIY. Modern-day DIY goes beyond the home production activities described by Becker (1965) (e.g., cleaning) and has become a source of utility by itself because of its embodied process benefits (Xie et al., 2008). As we explained in our literature review, DIY can be self-rewarding; it has become a "morally uplifting way of utilizing spare time" (Atkinson, 2006, p. 1).

Our model proposes that agents maximize utility over four factors: consumption of goods bought on the market c_m, consumption of goods produced through DIY c_{DIY}, time spent on the labor market h_m, and time spent on DIY h_{DIY}. In doing so, agents are constrained by their total income I and discretionary time T, their ability to produce DIY goods $g(.)$, and the assumptions that consumption (c_m; c_{DIY}) and time spent (h_m; h_{DIY}) cannot be negative. Thereby, the maximization problem becomes as follows:

$$\text{Subject to :} \quad \begin{aligned} & maxU(c_m, c_{DIY}, h_m, h_{DIY}) \\ & c_m \leq I \\ & h_m + h_{DIY} \leq T \\ & c_{DIY} \leq g() \\ & c_j \geq 0 \\ & h_j \geq 0 \end{aligned}$$

To further specify the maximization problem, we use insights into the functional form of the utility function by Benhabib et al. (1990, 1991). That is, the agent's preferences are defined by Eq. (1) below:

$$U = ln(c_m + c_{DIY}) + Aln(T - h_m - h_{DIY}) + b(w,\theta) \bullet h_{DIY} \quad (1)$$

In which $A \geq 0$ and measures the agent's preference for leisure, and $b(.) \geq 0$. We expand earlier economic work on time allocation by including the agent's preference for process benefits derived from DIY $b(w,\theta)$. Findings by Williams (2004, 2008) show that people's preferences for process benefits are not only determined by exogenous factors θ but also correlate with their level of income —such that $b'(w) > 0$ (in other words: $b(.)$ increases with wage w). Whereas people with low incomes more often develop DIY goods out of necessity (Rajan, 2021) for their consumption value c_{DIY}, people with high incomes are more often driven by self-actualization and enjoyment (Williams, 2004). Finally, in line with Benhabib et al. (1990, 1991), we assume that utility is marginally decreasing in these factors by taking the log over consumption and leisure time.

Before we can derive the effects of personal resources on DIY, we need to integrate the agent's constraints for the consumption of market goods c_m and DIY goods c_{DIY} into the utility function above. We simply propose that the agent's income I is determined by the product of the agent's wage w and labor hours h_m and that a share of the wage is spent on market goods ($0 \leq \delta \leq 1$). Hence, the budget constraint for market consumption becomes: $c_m \leq \delta w h_m$. For DIY, "it could be argued that when consumers take part in production processes, they either contribute time or money (or a mix of both)" (Rayna and Striukova, 2021, p. 223), complemented by their competencies (Xie et al., 2008). Accordingly, the other share of the agent's wage $(1 - \delta)w$ is used to buy raw materials for DIY. Along with hours spent on DIY h_{DIY}, this enters a Cobb-Douglas production function defining the agent's ability to produce DIY goods: $c_{DIY} \leq \varphi((1-\delta)w)^{\alpha} h_{DIY}^{\beta}$. Parameter φ reflects the agent's (technical) DIY competencies, while parameters α and β represent the marginal returns to monetary and time inputs, respectively. We can assume diminishing returns to both of these input factors ($0 < \alpha < 1$ and $0 < \beta < 1$) as studies on the broader phenomenon of home production (see, e.g., Gronau, 1977) and more closely related studies on HHS innovation (see, e.g., Baldwin et al., 2006) find diminishing returns to (time) investments in these activities. As Baldwin et al. (2006) explained, the probability that a particular design improves diminishes with resources spent as the design space surrounding a new opportunity matures. Thereby, the function over which the agent maximizes utility becomes:

$$maxU = ln(\delta w h_m + \varphi((1-\delta)w)^{\alpha} h_{DIY}^{\beta}) + Aln(T - h_m - h_{DIY}) + b(w,\theta) \bullet h_{DIY} \quad (2)$$

Before we conducted a comparative statics analysis to evaluate the impact of personal resources on DIY, we concluded that an optimum exists. For relevant derivations, we refer to online appendix A1.

3.2. Personal resources and DIY

As a first indicator of how personal resources affect DIY, we study the effect of income. In our model, this implies evaluating the effect of a wage increase on the hours spent on DIY: $\frac{\partial h_{DIY}^*}{\partial w}$. In online appendix A2, we find that the effect of income on hours spent on DIY is positive ($\frac{\partial h_{DIY}^*}{\partial w} > 0$) if and only if:

$$(\alpha - 1)c_m + B_w X > (1 - \alpha)c_{DIY} \quad (3)$$

In which B_w is the first derivative of process benefits with respect to wage (i.e., $\frac{\partial b(w,\theta)}{\partial w}$), which we can assume to be positive—research has shown that the process benefits of DIY (enjoyment, self-expression, etc.) increase with income (Williams, 2004, 2008). X is a term simplifying the product of the agent's wage w and total consumption squared $(c_m + c_{DIY})^2$ divided by the first derivative of the agent's DIY Cobb-Douglas production function with respect to hours spent on DIY $\frac{\partial g()}{\partial h_{DIY}} (= G_{hDIY})$ (see online appendix A2). By definition of the model, X is positive, so the overall term $B_w X$ can be assumed to be positive as well.

Expression (3) shows that the higher the agent's process benefits obtained from DIY when income increases, the more likely a wage increase results in increased DIY production. Recall that $0 < \alpha < 1$, indicating diminishing returns to the share of the agent's wage invested in DIY. This implies that the term $(\alpha - 1)c_m$ is negative, while—on the right-hand side of expression (3)—the term $(1 - \alpha)c_{DIY}$ is positive. Effectively, $B_w X$ may compensate for the negative term $(\alpha - 1)c_m$, and this is increasingly likely the higher the agent's income.

In other words, though a wage increase might be better spent on market consumption when evaluating the consumption value of DIY goods versus market alternatives, the process benefits attached to developing DIY goods can outweigh this deficit and make DIY a favorable activity. The possibility of such a scenario is substantiated by literature on the so-called 'IKEA effect' (Marsh et al., 2018; Mochon et al., 2012; Norton et al., 2012). The 'IKEA effect' shows that people's valuation of DIY goods is often higher than their valuation of market goods, even when self-created products are amateurish compared to those made by experts (Norton et al., 2012).

Due to obtained process benefits, our model predicts that when income increases, the development of DIY goods becomes increasingly likely—even when agents face increasing opportunity costs of not working. Ceteris paribus, the positive effect of income on DIY hinges on the observation that process benefits B_w derived from DIY increase with income, as DIY becomes more of an uplifting way to spend time when not being driven by economic necessity. We hypothesize:

H1a. : Individuals' development of DIY goods increases with their level of income.

As a second indicator of personal resources, we study the effect of discretionary time—being the agent's time free from obligations (von Hippel, 2017). In our model, an increase in discretionary time implies an upward shift in the budget constraint in $h_m + h_{DIY} \leq T$. One can think of different scenarios in which this would occur. For example, when children move out of their parental home and need fewer hours of care. Evaluating the effect of discretionary time T on the hours spent on DIY (i.e., $\frac{\partial h_{DIY}^*}{\partial T}$, see online appendix A3), we find that T has a positive effect on h_{DIY}^* if and only if:

$$\frac{\delta w}{((1-\delta)w)^{\alpha}} > \beta \varphi h_{DIY}^{\beta - 1} \quad (4)$$

Recall that we can assume $0 < \beta < 1$—so the term on the right-hand side is most likely smaller than one. Only in the case of an extremely competent creator, where $\varphi > 1$ (meaning that the agent can create more consumption value at home than by working on the market, disregarding process benefits from DIY), the right-hand side can be higher than one. A study by Watson and Shove (2008) on the role of competencies in DIY shows that such a scenario is unlikely when disentangling the assistance of tools and human competencies. Likewise, HHS innovation studies have shown that only a minority of consumers developing innovations are technically trained and/or have work experience in a technical setting, suggesting that for a representative agent $\varphi \leq 1$ (von Hippel, 2017).

The left-hand side equals one if the agent would face constant marginal returns to investments in DIY ($\alpha = 1$) and if the agent would spend as much income on raw materials for DIY as the agent would spend on market goods to consume directly. Empirical evidence on DIY shows that expenditures on raw materials used for DIY are generally significantly less than consumers' expenditures on market goods (cf. Mintel, 2006). Furthermore, we assumed $0 < \alpha < 1$. This means that the left-hand side is higher than one. Hence, we hypothesize discretionary time to have a positive effect on the development of DIY goods:

H1b. : Individuals' development of DIY goods increases with their discretionary time.

3.3. Personal resources and HHS innovation

As discussed above, functional novelty determines whether DIY goods are also innovative. Combining expressions (3) and (4) with empirical evidence on HHS innovation, we formulate a hypothesis and a research question.

Concerning income, we hypothesize that—given that the agent develops DIY goods—income negatively relates to the likelihood that the agent develops a HHS innovation. To illustrate our argument, we consider the cases of people with very low incomes (the poor) and very high incomes (the rich). At very low incomes, process benefits can approach zero ($b(w,\theta) \to 0$): poor agents develop DIY goods (mainly) out of necessity (Williams, 2008). Then, the effect of income on DIY can be rewritten such that its direction is defined by $\frac{\alpha-1}{1-\beta}$ (see online appendix A2). The decision to increase or decrease DIY production is based entirely on the agent's marginal return to money α and time β invested in DIY. This implies that poor agents carefully assess where their resources are spent most productively when maximizing their utility—on DIY or by directly acquiring goods on the market. For the poor, it is use-value that matters, not process benefits.

For agents with high incomes, for whom process benefits do matter, the effect of income on DIY can be rewritten such that its direction is defined by $\frac{\alpha-1}{1-\beta} + \frac{B_w w(c_m+c_{DIY})}{(1-\beta)G h_{DIY}}$ (see online appendix A2). The effect of income on DIY is likely to be positive in this case, as the latter term increases substantially with income (echoing our hypothesis H1a). Necessary for our hypothesis on HHS innovation, however, is that rich agents' decision to develop more DIY goods is driven by their anticipated process benefits—the use benefits only play a marginal role in their decision-making. In summary, our model implies that poor people carefully assess the consumption value of DIY versus market goods, while, for the rich, process benefits are more influential. Hence, we theorize a crowding-out effect: income can crowd out people's focus on the actual use-value of their DIY goods.

Especially for DIY goods with functional novelty (i.e., HHS innovations), use benefits will be high. HHS innovations enable their developers to perform functions that were not possible before, and that cannot be found in existing products sold on the (local) market (de Jong et al., 2015; von Hippel, 2017). As low-income DIYers more carefully assess the use-value of their self-provisioned good, while high-income DIYers focus on process benefits, we can expect that low-income DIYers are more likely to develop DIY goods that are innovative:

H2. : Given that individuals develop DIY goods, the likelihood that their DIY goods are innovative decreases with their income.

This hypothesis is in line with the observation by Praceus and Herstatt (2017) that people in low-income areas are more likely to innovate because their resource constraints force them to find creative solutions to a lack of market alternatives. Our hypothesis is also consistent with observations that some people in affluent environments keep tinkering with personal designs or software without any consumption need in mind (cf. Hann et al., 2013; Lakhani and Wolf, 2005) and that, for some consumers, process benefits alone are sufficient to compensate for their development efforts (Raasch and von Hippel, 2013).

Next, concerning discretionary time, intuitively, we would expect a similar, negative effect on developing HHS innovations. However, previous research findings and our theoretical model leave room for miscellaneous interpretations, and for this study, we formulate a research question about the relationship between discretionary time and HHS innovation.

Recall that the effect of discretionary time on DIY is positive if: $\frac{\delta w}{((1-\delta)w)^{\alpha}} > \beta\varphi h_{DIY}^{\beta-1}$ (expression (4)). We hypothesized this expression to hold since people's expenditure on market goods δ is generally much higher than their expenditure on raw materials used for DIY $(1-\delta)$, and their technical competencies are generally not such that they produce more consumption value at home as compared to what can be acquired on the market ($\varphi \leq 1$).

Studying expression (4) in light of HHS innovation, we know that HHS innovation connects with the expression through the agent's (technical) competencies φ. HHS innovators do not resemble the general population of citizens but are a subsample that is better educated and has more technical work experience (see, e.g., von Hippel, 2017; von Hippel et al., 2012;). Hence, our intuition is that the competencies of HHS innovators are significantly higher than those of an agent representative of the general population—i.e., $\varphi_{HHS} > \varphi$—implying that, for HHS innovators, the right-hand side of expression (4) is higher. This can result in a situation where the right-hand side of expression (4) exceeds the left-hand side. Then, an increase in discretionary time, for HHS innovators specifically, would be associated with less time invested in the development of innovations. However, neither from our theoretical model nor from empirical studies can we unambiguously hypothesize such a negative effect.

Empirical studies, to date, provide no clear guidance on the difference in φ when comparing HHS innovators to the general population. Therefore, with the other parameters on the left-hand side (δ; α) and right-hand side (β) of expression (4), we cannot exclude the scenario that, also for HHS innovators, the left-hand side exceeds the right-hand side. Furthermore, as we explained in Section 2.2, there have been no studies that directly study the relationship between discretionary time and HHS innovation, and even the related study by Agrawal et al. (2018, p. 1056) shows that the effect of "slack time on innovative outcomes is ambiguous". Two opposing mechanisms drive their ambiguous results: slack time (1) can cause innovators to be less selective when screening out ideas—decreasing the quality of ideas—but (2) allow innovators to spend more time on improving ideas—facilitating the quality of ideas (Agrawal et al., 2018).

Altogether, our theoretical model and past studies do not allow for the formulation of an unambiguous hypothesis regarding the effect of discretionary time on HHS innovation. We feel that this is a matter to further explore empirically and, instead, formulate the research question:

RQ. : Given that individuals develop DIY goods, how is the innovativeness of their DIY goods related to their discretionary time?

4. Data

4.1. Sample

We tested our hypotheses on a sample of consumers in the United Arab Emirates (UAE). Since the discovery of oil and follow-up investments by local and foreign investors, the country has had a booming economy and a rapidly growing population. With an estimated population of nearly 10 million citizens in 2020, the population sky-rocketed if we compare this number to the total of 2.3 million people inhabiting the UAE in 1989.

UAE's citizens vary in their levels of income and discretionary time, providing us with a suitable context for our research. Only an estimated 10 % of today's population consists of locals (Emirati), while around 90 % comes from abroad. These include a minority of prosperous laborers (e.g., engineers, managers, researchers, and advisors) from Western countries (e.g., Europe, Russia, North America), a middle class of workers from the Middle East (e.g., Jordan, Egypt, Oman) and India and Pakistan, and a substantial group of contract workers from Asian countries including Sri Lanka, Philippines, and (again) India and Pakistan. In our discussion section, we reflect on the advantages and disadvantages of our research context.

Our data collection was sponsored by the UAE's Prime Minister's office as part of a scientific study to measure HHS innovation and identify policy implications. The data were collected by NR Research, a local marketing research company in Dubai, by means of computer-

assisted telephone interviewing. NR obtained our initial sample with a random number generator covering cell phones and landlines. This method ensures that each citizen has an equal chance of ending up in the sample (Malhotra and Birks, 2006). We recognized that contract workers have scant leisure time, so most telephone interviews were attempted in the later evenings and during the weekends.

In advance, we trained NR's workforce by introducing them to the fundamental concepts of our study (i.e., DIY, HHS innovation) and gave feedback on a series of test interviews. In the introduction to each survey, the interviewer indicated that the research was done on behalf of the Prime Minister's office. The interviewer then checked if the respondent was at least 18 years old. In particular, the interviewer asked to speak to the person aged 18+ in the household whose birthday would come up first—allowing us to naturally randomize the sample.

Over four months, contact attempts were made with 18,005 UAE citizens. In total, 6902 citizens remained out of reach—meaning no answer after five attempts, no reply, or voicemail—or were <18 years old. Another 8102 citizens were unwilling to take the survey. Ergo, we obtained responses from 3001 UAE citizens. Concerning our variables of interest, however, we faced missing values, especially for income. After the listwise deletion of such cases, we ended up with a dataset of 2728 citizens—making the response rate 15.2 % (or 24.6 % of those we had reached).

4.2. Identifying DIY goods and HHS innovations

We applied screening questions described by de Jong (2016) that collectively determine whether consumers developed a DIY good, and, if yes, whether their DIY good is innovative. The same questions have been used in surveys in over ten countries (von Hippel, 2017).

Individual householders tend to associate innovation with high-tech and are usually ignorant about what innovation entails. Accordingly, the survey script did not ask for 'innovations' but offered a range of specific cues proof-tested in previous studies (de Jong, 2016; Kuusisto et al., 2013): computer software; household items; transportation and vehicle-related; tools and equipment; sports, hobby, and entertainment; children and education; healthcare and medical; and other.

Our interviewers introduced the survey as follows: *"My next questions are about what you do in your free time. During this time, you may engage in various creative behaviors, I will give some examples."* Then they read out the first cue, "*computer software by programming original code*", and asked, *"In your free time, did you ever create this in the past three years?"*. Next, the other cues (household items, etc.) were offered one by one (cf. de Jong, 2016). If respondents said 'yes' to any cue, they had potentially developed a DIY good. In case they could mention several examples, we asked them to focus on their most recently developed case to obtain a random sample of creations that were still on top of the respondents' minds (Malhotra and Birks, 2006). Next, to avoid false positives, we added a screening question: we explicitly checked if the respondent had created the good for their job or because their employer had asked for it. This excluded any creations that belonged to the business sector.

Next, we asked two screening questions to check whether a reported DIY good is also innovative. First, respondents themselves indicated if they could have bought a product with similar functions on the market. If yes, their creation was considered a DIY good but not a HHS innovation with an embodied novel function. Second, respondents described the developed good and explained what was new about it (open-ended question). Two coders independently reviewed the answers to rate the (lack of) functional novelty. Specifically, they assessed whether the DIY good was 'new' given that the product and its functionality did not clearly exist already. The DIY good was considered to be no HHS innovation when at least one of both coders indicated that some novel function was lacking. In case of doubt, for example, when the open-ended description was insufficiently detailed, we followed the respondent's assessment of whether the DIY good was innovative. The kappa statistic was 0.83, indicating good inter-rater agreement (Landis and Koch, 1977).

Respondents were considered to have produced DIY output in case they developed at least one good outside their work hours in the past three years; this applied to 239 respondents (8.8 %). Examples of reported DIY goods were *"I built my own device to irrigate gardens. There's nothing new except the way it looks."* (tools and equipment; DIY good but not coded as innovative because a similar product was available on the market), and "*A decorative bedside lamp. I wanted to do one myself since the materials were available. It was my own style, you cannot find it on the market."* (household item; coded as DIY but not as innovative because the coders did not see a novel function enabled by the bedside lamp).

Respondents were considered to be also HHS innovators when they had developed at least one good that was not yet available on the market, and their description indicated functional novelty; this applied to 123 respondents (4.5 %). Examples of reported HHS innovations were *"I hold camels and created a medicine for drying inflammation in the pores of my camels' heads. It cleans the pores, and it is made of natural products."* (health and medical) and *"A car engine with a design different from all current engine systems. Fuel efficient and easy to repair, and the number of engine parts is much lower than regular engine parts."* (transport and vehicle-related).

In the rest of the survey, we collected data about the respondents' income, time spent at work (to proxy their discretionary time), and a range of control variables discussed hereafter. Our approach to distinguishing HHS innovations within a broader category of DIY goods deviates from past studies, which ignored reported cases without functional novelty. Past studies considered DIY a nuisance (e.g., Chen et al., 2020; Kim, 2015; von Hippel et al., 2012) but here we regarded lack-of-functional novelty as an interesting source of variance, enabling us to analyze differences in factors associated with DIY goods versus HHS innovations.

4.3. Variables

Table 3 shows the variables we used in our analyses. Effectively, 8.8

Table 3
Variables.

Variable	*Description*	*Mean*	*SD*
DIY output	In the past three years, respondent created a good in the respondent's discretionary time (0 = no, 1 = yes)	0.088	0.283
HHS innovation	In the past three years, respondent created a good with functional novelty in the respondent's discretionary time (0 = no, 1 = yes)	0.045	0.208
Income	Respondent's monthly income in 1000 Dirham (AED)	9.398	10.439
Discretionary time	Respondent's estimated discretionary time per week, in hours (computed as 168 −/− 56 (assumed sleeping time) −/− reported time for work	71.622	23.931
Gender	Respondent was (0) male or (1) female	0.247	0.432
Age	Respondent was (1) 18–24 years, (2) 25–34 years, (3) 35–44 years, (4) 45–54 years, (5) 55 years or more	2.547	1.068
Collective household	Respondent lived in a collective household (0 = no, 1 = yes)	0.247	0.432
Technical education	Respondent had a technical or science degree, or accreditation in a technical skilled trade (0 = no, 1 = yes)	0.305	0.460
Technical work experience	Respondent had work experience in a technical job or profession (0 = no, 1 = yes)	0.321	0.467
Education level	Respondent's best educational attainment was (1) none, (2) primary school, (3) secondary or tertiary school, (4) bachelor degree, (5) master degree or higher	3.517	0.899

Notes: n = 2728. SD = Standard Deviation.

% of our sample had created a DIY good, and 4.5 % had created a DIY good that included a novel functionality—a HHS innovation. A frequency of 4.5 % is in line with the frequencies encountered in other national surveys (von Hippel, 2017).

Income was measured in thousands of dirhams (AED), the UAE's local currency. Discretionary time available was estimated in hours per week. We calculated the respondents' discretionary time by subtracting from 168-week hours: self-reported work hours (time spent weekly on a job or business) and an assumed 56 sleep hours.

Other variables in Table 3 are control variables. We included demographic factors (gender, age) as well as technical education and experience, and education level, as these are relevant antecedents of HHS innovation (de Jong and von Hippel, 2022; von Hippel, 2017) and DIY (e.g., Williams, 2008; Wolf and McQuitty, 2011). Notice that only 25 % of the respondents were female. This reflects the dominant presence of temporary contract workers in the country, who are generally males. We also added a variable if the respondent lived in a collective household, which is common in the UAE. Individuals living in collective households may be constrained in physical space to engage in DIY and innovation.

5. Findings

The correlations between our variables are shown in Table 4. Concerning our variables of interest, DIY output and HHS innovation are positively related ($r = 0.701$) as an artifact of how we collected our data. Also, our independent variables, income and discretionary time, are modestly and negatively related ($r = -0.163$), which justifies estimating their association with DIY output and HHS innovation separately (income and discretionary time cannot be considered reflective indicators of a single personal resource construct).

The correlation coefficients raise no concerns for multicollinearity. In the regression models presented hereafter, variance inflation factors (VIFs) are within acceptable limits, as the highest VIF in our models is 1.84. In general, when VIFs <10, multicollinearity is not considered problematic, and when VIFs <2.5, multicollinearity is not regarded to play any role (Malhotra and Birks, 2006).

5.1. Regression results

To test our hypotheses, we estimated a sequential logit model. Sequential logit models allow for studying the effects of explanatory variables on the probabilities of passing a set of transitions (Buis, 2013). In our study, the first transition is the probability that individuals developed a DIY good. The second transition is the probability that someone with a developed DIY good also developed an innovation. We included income, discretionary time, and all control variables in our model estimation: see Table 5.

The overall model fit is good (Wald-$\chi^2 = 124.24$ with $df = 8$, $p < .01$).

Table 5
Sequential logit regression of DIY output and HHS innovation.

Step 1. dependent variable: DIY output		
Baseline value:	0.0876**	
Marginal effects:	*dy/dx*	*SE*
Income	0.0024**	(0.0006)
Discretionary time	0.0011**	(0.0003)
Female	0.0098	(0.0130)
Age	−0.0037	(0.0053)
Collective household	−0.0236	(0.0139)
Technical education	0.0057	(0.0149)
Technical work experience	0.0484**	(0.0162)
Education level	0.0248**	(0.0074)

Step 2. dependent variable: HHS innovation		
Baseline value:	0.5636**	
Marginal effects:	*dy/dx*	*SE*
Income	−0.0067*	(0.0031)
Discretionary time	−0.0041*	(0.0017)
Female	−0.0976	(0.0854)
Age	0.0014	(0.0310)
Collective household	−0.0381	(0.1135)
Technical education	0.0281	(0.0820)
Technical work experience	−0.0334	(0.0822)
Education level	0.0140	(0.0460)
Model fit:		
Wald-χ^2 (df)	124.24 (8)**	
Observations	2728	

Notes: Average marginal effects (dy/dx) are shown. Robust standard errors (SE) in parentheses. Two-tailed significance: **p < .01, *p < .05.

As indicated by the first transition, our regression shows a significant positive effect of income and discretionary time on developing a DIY good ($p < .01$)—confirming hypotheses H1a and H1b.

Focusing on the second transition, estimating the likelihood that someone with a DIY good created an innovation, we observe that this is negatively affected by income and discretionary time ($p < .05$). Hence, the results confirm hypothesis H2, while the answer to our research question is that, when more discretionary time becomes available, the likelihood of a DIY good being innovative diminishes. Figs. 2 and 3 show the effects we found in more detail.

Fig. 2 visualizes the positive effect of income on DIY output, with the probability of DIY output being around 6 % for the lowest incomes to almost 15 % for the highest incomes in our data. Given that a DIY good has been developed, the effect of income shows the opposite for HHS innovation. We see that a DIYer's probability of developing a HHS innovation is over 60 % for those with low incomes but around 42 % for those earning the highest income.

A similar pattern prevails for the effects of discretionary time (see Fig. 3). The probability of DIY output is just below 5 % for severely time-constrained people—having 12 h of available discretionary time per

Table 4
Correlation matrix.

	1	2	3	4	5	6	7	8	9
1 DIY output									
2 HHS innovation	0.701**								
3 Income	0.147**	0.093**							
4 Discretionary time	0.063**	0.009	−0.163**						
5 Female	0.036	−0.006	−0.118**	0.389**					
6 Age	0.065**	0.041*	0.448**	−0.041*	−0.043*				
7 Collective household	−0.091**	−0.055**	−0.299**	−0.136**	−0.091**	−0.202**			
8 Technical education	0.113**	0.090**	−0.271**	0.016	−0.044*	0.169**	−0.108**		
9 Technical work experience	0.126**	0.097**	0.252**	−0.076**	−0.090**	0.127**	−0.083**	0.642**	
10 Education level	0.139**	0.099**	0.419**	0.062**	0.126**	0.256**	−0.278**	0.311**	0.249**

Notes: n = 2728. Pearson correlations are shown.
** p < .01.
* p < .05.

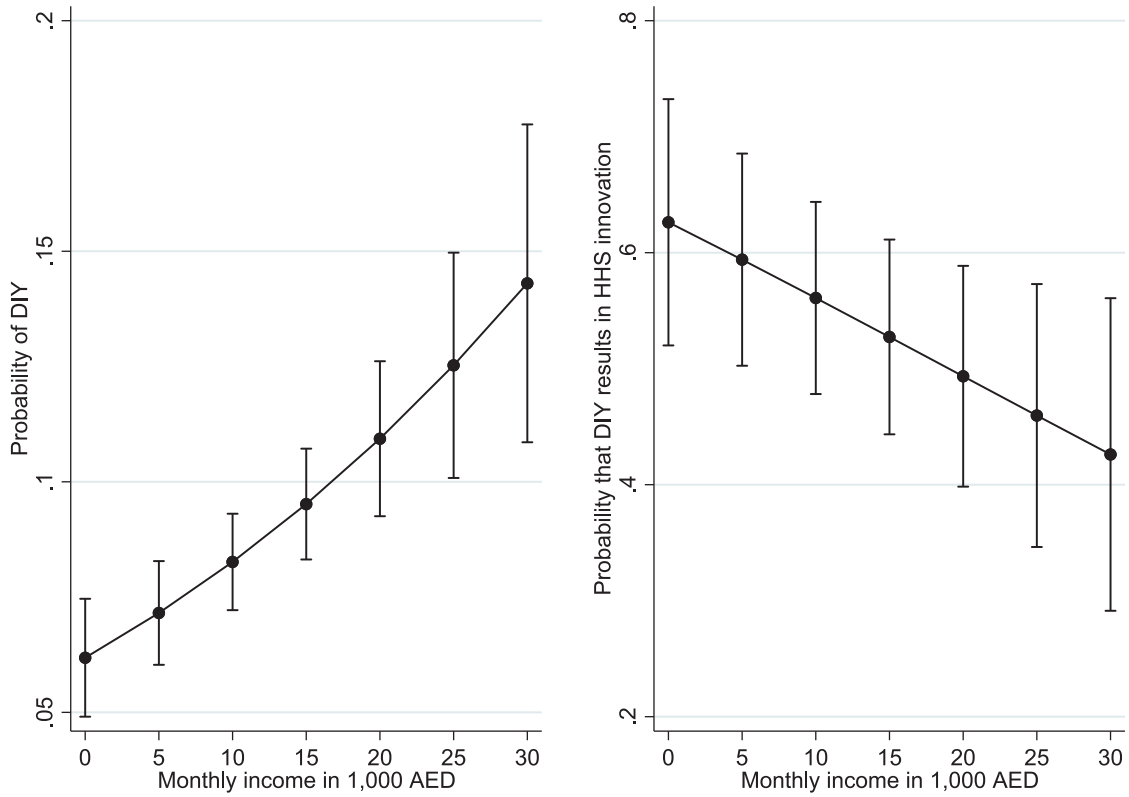

Fig. 2. The probability of DIY output and HHS innovation for different levels of income.
Notes: Predicted probabilities are shown with 95 % confidence levels.

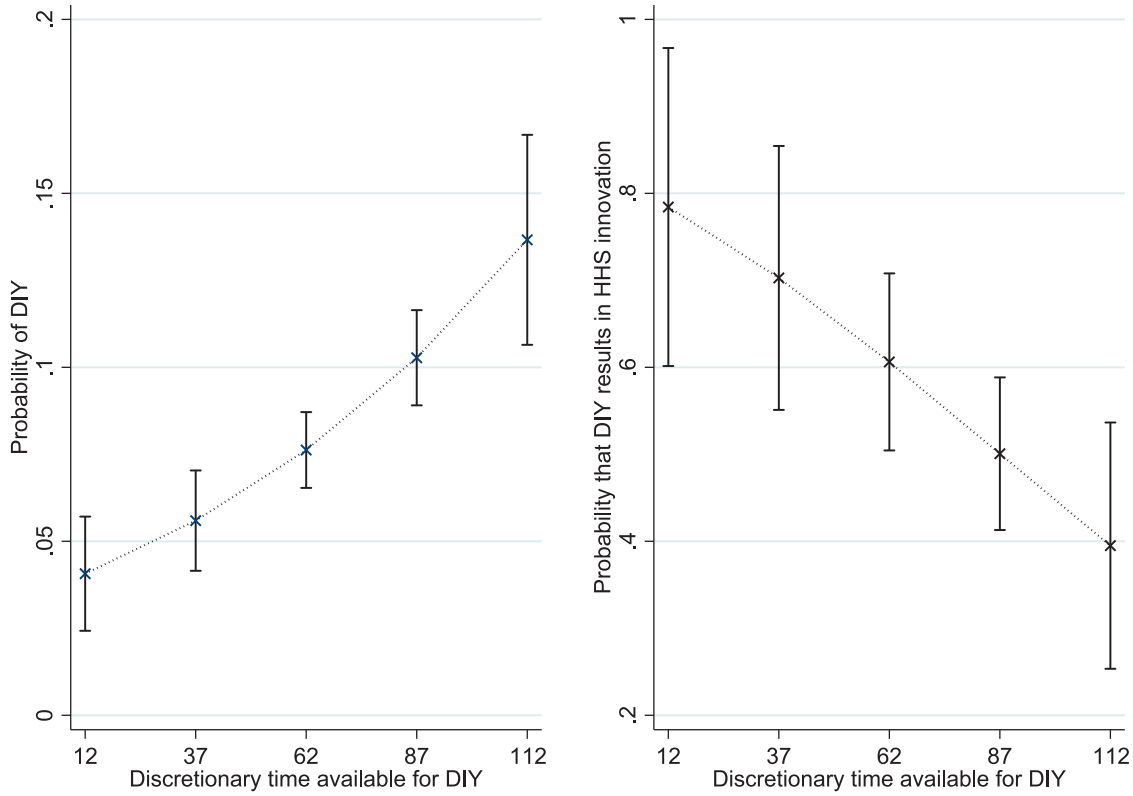

Fig. 3. The probability of DIY output and HHS innovation for different levels of discretionary time.
Notes: Predicted probabilities are shown with 95 % confidence levels.

week—while it is around 14 % for people having 112 h of available discretionary time per week. The probability that a DIYer develops an innovation is just below 80 % when the DIYer only has 12 h available per week, while this probability drops to 40 % for individuals with the most discretionary time. As an artifact of how the data were collected, we speculate that respondents with a lot of discretionary time have less work experience. Accordingly, we suspect these respondents to have fewer (technical) competencies learned on the job that can be employed to self-provision goods, decreasing the probability of HHS innovation. Evidence of this potential mechanism is also provided in Table 4, which shows a significant negative correlation between discretionary time and technical work experience. With our theoretical model, such a mechanism could not have been hypothesized as we did not endogenize the agent's (technical) competencies.

Next, since our approach deviates from previous studies of HHS innovation, we explore the association between income, discretionary time, and HHS innovation when we would ignore its embeddedness in DIY. We estimated a simple probit model (see Table 6), as has been done in previous studies.

Table 6 is well in line with earlier HHS innovation studies. Chen et al. (2020) found similar results in their study of Chinese citizens—i.e., a positive association between income and HHS innovation. Discretionary time has not been investigated before, but Tables 5 and 6 suggest that no relationship with innovation would be found unless the embeddedness of HHS innovation in DIY is considered.

5.2. Robustness checks

As a robustness check, we ran the sequential logit model reported in Table 5 with an additional set of control variables. This set of controls, first, included the respondents' access to the Internet. Fox (2014) argued that individuals' ability to engage in DIY is likely to be limited when they have poor internet access. Similarly, HHS innovation scholars have also stressed the importance of the Internet (von Hippel, 2017). Second, we controlled for the respondents' nationality to account for the fact that many of the UAE's citizens come from abroad. We added dummy variables indicating whether respondents were expats from a Western country, an Arabian country, India, Pakistan, the Philippines, Sri Lanka, another Asian country, or another non-Asian country to control for the main immigrant groups within the country. None of the conclusions drawn from our results in Table 5 was affected.

Next, we estimated an alternative Heckman probit model with selection instead of a sequential logit model. We specified DIY output as the dependent variable in the selection equation and HHS innovation as the dependent variable in the main equation, then included income, discretionary time, and all control variables as predictors. The model was identified because technical work experience and education level were related to DIY output but not to HHS innovation. Our estimates were very similar, with a significant positive effect of income and discretionary time on the likelihood that one develops DIY output ($p < .01$) and a negative effect of income and discretionary time on the likelihood that one develops an innovation ($p < .05$).

Finally, we recognized that the responses to our survey could have been selective. Although we did not have an up-to-date sampling frame with national coverage, the UAE's Prime Minister's office did provide us with their best estimates of population statistics that enabled us to compute weight variables. We re-estimated our sequential logit model with two weight variables that make the sample more representative of the population according to these best estimates. The first weight variable we constructed using statistics on gender, age, and emirate of residence (Abu Dhabi, Dubai, Sharjah, or the Northern Emirates). The second weight variable we constructed based on nationality (UAE, Arabian, Western, India, Pakistan, Philippines, Bangladesh, other Asian, other non-Asian). Our weighting scheme and the results of the weighted sequential regression analyses can be found in the online appendix B of this paper.

Table 6
Probit regression of HHS innovation.

Dependent variable: HHS innovation		
Baseline value:	0.0451	
Marginal effects:	*dy/dx*	*SE*
Income	0.0009*	(0.0004)
Discretionary time	0.0002	(0.0002)
Female	−0.0037	(0.0093)
Age	−0.0025	(0.0041)
Collective household	−0.0109	(0.0100)
Technical education	0.0074	(0.0107)
Technical work experience	0.0246*	(0.0115)
Education level	0.0151**	(0.0056)
Model fit:		
Wald-χ^2 (df)	57.7 (8)**	
Observations	2728	
Pseudo R^2	0.051	

Notes: Average marginal effects are shown. Robust standard errors in parentheses. Two-tailed significance: **p < .01, *p < .05.

6. Discussion

The contribution of this paper is threefold. First, we expand the HHS innovation literature by connecting the concept to the literature on DIY. Following de Jong et al.'s (2021) call, we recognized important parallels: HHS innovation and DIY describe the active production of goods, where individuals design and create goods by themselves. Both are increasingly observed due to similar trends (e.g., availability of low-cost tools), and continued growth is expected. Also, both concepts are driven by similar motives that can be aggregated to use benefits/consumption value (e.g., to satisfy personal needs) and process benefits (derived from engaging in DIY/innovation regardless of the outcome; such as enjoyment, learning, self-actualization) (Chen et al., 2020; de Jong et al., 2015; Kuznetsov and Paulos, 2010; Williams, 2004, 2008; Wolf and McQuitty, 2011, 2013; Xie et al., 2008). Finally, we identified as the main distinction that HHS innovations are marked by functional novelty, so that HHS innovations are a subset of DIY goods developed by individuals in the household sector.

The second contribution is that HHS innovation's embeddedness in DIY helps us to understand better when and how HHS innovations emerge. Specifically, we recognized previous mixed claims about the role of personal resources in HHS innovation and, based on Becker (1965), developed a time-allocation model that helps to explain how personal resources affect the development of DIY goods and HHS innovations. We hypothesized that resource-rich people are more likely to develop DIY goods (as they derive more benefits from the DIY process), while—given that DIY output is realized—people in low-income groups are more likely to develop DIY goods with functional novelty (as the actual consumption value of DIY goods matters more for their decision to engage in DIY). Specifically, the mechanism in our theoretical model that drives the positive effect of income on DIY (process benefits) illuminates that wealthy individuals may develop DIY goods even when the actual use-value of these goods is very low. Such behavior has, e.g., been observed for groups of hackers contributing to open-source software—who are generally relatively wealthy (Hann et al., 2013) and can decide to do so purely for fun without ever using the software that they contribute to (Lakhani and Wolf, 2005). Individuals with fewer resources, however, are less triggered by process benefits and require more use benefits to engage in DIY. As functional novelty results from an individual's focus on the actual use of the individual's good, the resource-poor are more likely to create innovative goods.

For discretionary time, our model did not allow us to formulate an upfront hypothesis about its effect on innovation, but, similar to the effects of income, we found a positive effect on DIY output and a negative effect on HHS innovation. A potential explanation can be that individuals who spend more discretionary time on DIY spend less time

on the labor market and, thereby, develop fewer (technical) competencies to employ when self-provisioning goods—leading to less innovative outcomes.

Our findings clarify the previous mixed evidence on the role of income. If we would ignore DIY and simply estimate a regression of HHS innovation on individual-level antecedents (Table 6), we find a positive relationship. This is entirely in line with Chen et al.'s (2020) survey of Chinese citizens. In contrast, if we would develop case studies of individuals producing goods for themselves and then explore the characteristics of those who develop goods with functional novelty, we would identify low-income people (see step 2 in Table 5). This is essentially the kind of data considered in studies by Praceus and Herstatt (2017), Gupta (2013), and Rajan (2021). Concerning the question posed in the title of our paper, we conclude that resource-rich people are more likely to engage in DIY, but within the population of DIYers, it is the resource-poor who are relatively more innovative in their development outcomes.

As a third contribution, we connect the literature on DIY and HHS innovation to economic theory. Becker (1965) described households not only as consumers but also as production facilities. Rational choice economists usually regarded work (including the development of DIY goods) as an inherent disutility, which is hard to synthesize with the motives and, in particular, process benefits discovered later in DIY and HHS innovation studies. Consequently, some economists struggled to explain the positive effect of income on engagement in DIY using traditional economic theory (Brodersen, 2003). By modeling the process benefits of DIY, our theoretical model can explain how income can positively impact DIY—even when individuals face higher opportunity costs of not working when their income increases.

As a final remark, by broadening its empirical scope and providing evidence that DIY is related to innovation—important for economic growth and societal welfare (Gambardella et al., 2017; von Hippel, 2017)—one can also consider our study a contribution to the DIY literature. We did a large-scale study on individuals that employ personal resources to create goods. Our data show that DIY goods encompass the development of tools and equipment, household items, sports-, hobby- and entertainment, and much more—suggesting that studies of DIYers that only focus on home remodeling and furniture design (e.g., Williams, 2004, 2008) can be broadened. Our findings underline Fox's (2014) theoretical propositions about DIY and innovation. By recognizing today's context of connected and empowered consumers and applying a corresponding definition of DIY (including classical and modern forms), we could link DIY with the development of functionally novel goods.

6.1. Implications for theory

The implications of our study are multifold. Our reconceptualization of HHS innovation as a subset of DIY redefines the position of HHS innovation in the broader literature on consumer behaviors aimed at self-provisioning. Based on a thorough literature study, we developed a conceptual framework (see Fig. 1) that can assist future studies in carefully addressing the scope of HHS innovation. As we have shown in this paper, doing so is crucial to disentangle the effects of antecedents on the design and production of goods by consumers (i.e., DIY) from the effects of antecedents on the likelihood that consumers are innovative.

An obvious first step is to expand our approach to other antecedents, including gender, education, technical work experience, lead-user characteristics, and personality traits (e.g., Fursov et al., 2017; Kim, 2015; Stock et al., 2016). Similar differences between DIY output and innovation may be hypothesized. For example, when it comes to personality traits, Stock et al. (2016) applied a stepwise approach to investigate how the ideation versus development of HHS innovations is related to individuals' Big Five traits. They found that ideation is associated with openness to experience while development is associated with being introverted and conscientious, and that personality traits required for HHS innovation are often not found within a single person. Although Stock et al.'s (2016) paper had a different focus, their results underline the possibility of antecedents having diverse effects related to various self-production efforts.

Continued work along these lines will also help to detect more relevant antecedents. Our findings regarding discretionary time illustrate this. To our knowledge, we were the first to explore its role in HHS innovation. From a classical regression approach (Table 6), we would have concluded that discretionary time is not significant. However, our two-step sequential logit model revealed a positive relationship with DIY and a negative one with innovation. This more fine-grained insight would have remained hidden if we had disregarded the embeddedness of HHS innovation in DIY.

Future work might, of course, also find that some antecedents operate very similarly when disentangling DIY and HHS innovation. This would be an important insight too. Researchers may then want to study these particular antecedents in relation to consumer engagement in DIY alone. This will save them the extensive budgets required to screen HHS innovations from survey data (cf. de Jong, 2016).

Finally, we suggest future work to continue exploring the role of (discretionary) time in detail. As mentioned in Section 2.2, Agrawal et al. (2018) found consumers' slack time to positively affect the number of innovative projects they launched on Kickstarter but also to increase the dispersion in the quality of these projects. Our findings somewhat echo these observations, as our data indicate a positive effect of consumers' discretionary time on DIY but a negative effect on the likelihood that their DIY efforts lead to innovative outcomes. The relationship between time and innovation is complex—this also stems from a parallel strand of literature in the business sector that we were notified of, where employees' available slack time was found to be non-linearly related (inverted U-shape) with innovation indicators (Nohria and Gulati, 1996)—and deserves further attention. Our study suggests that it might be worthwhile studying the role of skills learned on the job that consumers may (not) employ when they develop goods and how these skills are affected when consumers decide to spend more discretionary time on DIY at the expense of their work hours.

6.2. Implications for practitioners

The insights derived from our study have implications for practitioners, in particular commercial firms and public policymakers.

Firms can benefit from innovating consumers, e.g., by absorbing their innovations to bring to the market for general sale or learning from the need-information revealed by consumers' innovations (von Hippel, 2017). At a minimum, producers should monitor householders' innovation activities, as HHS innovations can complement or compete with their offerings (Gambardella et al., 2017). Our study provides directions on how HHS innovators can be identified. If a producer cannot identify consumers who are developing goods in their discretionary time (as is the case for most household items, tools, and equipment), a broad search will be needed. As casting a wide net requires substantial resources for screening, focusing on resource-rich individuals would be recommended to increase the odds of detecting innovations—although the producer would also find many goods developed for process benefits, with low actual use-value. In contrast, if a producer can a priori identify a group of DIYers relevant to the company's products (such as in communities of sports, hobbies, entertainment, medical, healthcare, software, or vehicle-related products), we would recommend paying more attention to resource-constrained individuals within these communities, in order to increase search efficiency.

For policymakers, researchers have suggested interventions like sponsoring online knowledge-sharing platforms (de Jong and Lindsen, 2021), Makerspaces (Halbinger, 2018), open-source intellectual property rights like creative commons licenses (von Hippel, 2017), and increasing a population's general access to the Internet (Fox, 2014). Our study implies that policy interventions will be more effective when targeted at those deprived of resources. Beyond that the additionality of

timesaving and/or tool-enabling interventions (e.g., platforms, Makerspaces), in general, is likely better for poor people, our findings show that providing additional personal resources to wealthy beneficiaries will make them develop relatively many goods without functional novelty. Assuming that particularly HHS innovation (and not DIY) has positive societal welfare effects (Gambardella et al., 2017; von Hippel, 2017), in situations of limited policy budgets, support for individuals with low income and/or discretionary time would be merited.

6.3. Limitations and future research

Finally, our study has limitations that create additional research opportunities beyond the suggestions we have provided already.

First, our study should be replicated with other samples. The context of the UAE was suitable to test our hypotheses because the country has a population with high differences in income and discretionary time (local Emirati and Western immigrants versus immigrants from Asian countries mainly involved in services and construction work). As such, our sample included both people living at first-world and third-world standards—matching our objective to shed new light on conflicting evidence regarding the role of income, which was reported in relatively affluent (Chen et al., 2020) and deprived countries (e.g., Gupta, 2006; Rajan, 2021). We point out that our interest was not to provide population estimates of HHS innovation (as done in previous studies, e.g., von Hippel (2017) or de Jong and von Hippel (2022)). Nevertheless, because citizens from another (first-world) country will likely show less variance in terms of resources (with the potential consequence of weaker correlations between resources, DIY, and HHS innovation), we believe replication studies are necessary to test our study's external validity. For such studies, we recommend cross-country surveys or designs in which resource-rich and resource-poor people are sufficiently present.

A second limitation is that we did not have a sampling frame in which the demographic data of prospects were known. In principle, our sampling method with a random number generator avoids sampling issues (Malhotra and Birks, 2006). Our findings were also consistent in robustness checks with weighted data, and overall, we found no evidence that selection bias distorted our analysis. Yet, we cannot exclude that our sample has been somewhat selective, especially in low-income groups. This is an argument for replication studies with sampling frames in which the distribution of prospects across demographic variables is known—so that the remaining selection bias can be controlled econometrically.

Overall, we conclude that embedding HHS innovation in a broader set of consumer behaviors, particularly DIY, helps us understand in what circumstances HHS innovations emerge.

CRediT authorship contribution statement

Max Mulhuijzen: Conceptualization; Methodology; Economic modeling; Formal analysis; Writing - original draft; Visualization.

Jeroen P.J. de Jong: Conceptualization; Methodology; Formal analysis; Investigation; Writing - review & editing; Supervision; Project administration; Funding acquisition.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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Online appendices

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