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UTILITY AND OPTIMIZATION'S DEPENDENCE ON DECISION-MAKERS' UNDERLYING VALUE-BELIEF SYSTEMS

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Abstract *This paper investigates how a consumer's utility and consequent optimization are determined by his/her natural endowments – self-awareness, imagination, conscience and free will. It focuses on such general utility that is a function in the dollar value of consumption, the number of hours spent on waged work and a particular value-belief system. For the third variable, we examine that it encourages the consumption of commodities and devalues waged job; it reinforces minimal commodity consumption; and it demands a non-standard optimization. While uncovering how an individual's marginal utility from commodity consumption or waged work varies respectively with different variables, such as non-waged incomes, etc., this paper demonstrates that when an individual decides on how much commodity is to be consumed and how much labor output is to be supplied to waged work by maximizing the corresponding utility, the person's utility and his/her method of optimization are exclusively defined by his/her value-belief system.*

Keywords: *commodity consumption; holistic thinking; mod function; values and beliefs; wage rate*

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1. INTRODUCTION

In studies of economic and social behaviors, a commonly employed approach is to first introduce an objective function, such as a utility function, a production function, a profit function, etc., and then based on some kind cost-and-benefit analysis of the underlying economic agent, this objective function is optimized (e.g., Friedman, 1953; Gilboa, 2010; Gul and Pesendorfer, 2008). However, such an approach does not capture real-life scenarios, although it has been repeatedly confirmed with falsified empirical evidence, as so criticized by behavioral economists (e.g., Mullainathan and Thaler, 2000; Kahneman, 2011). Hence, the following question arises naturally at the most fundamental level underneath all investigations of economic and social behaviors, if one focuses only on the micro-level of individuals: Does an economic man really go through such a general procedure when he/she decides on what to do in terms of making a consumption decision?

The importance of this question is well witnessed by the vast amount of related literature in the name of rationality, where the aforementioned, commonly employed approach in studies of economic and social behaviors is widely known as the assumption of rationality. Although such rationality has been criticized only in recent decades by behavioral economists, some degrees of an inherent uncertainty this assumption implicitly embodies has been broadly felt and explored by a good number of leading scholars (Hudik, 2019), including, among numerous others, Gary Becker (1962), Frank Lovett (2006), Fritz Machlup (1946), Ariel Rubinstein (1998), Paul Samuelson (1948), Herbert Simon (1986), LL Thurstone (1931), Max Weber (1949) and Glen Weyl (2019). In summary, after using this approach for so many decades, scholars are still debating on what the assumption of rationality really means (Hudik, 2019). This end indirectly explains the reason why a compelling need for a meaningful reconstruction of economic theory has been called for by recent events, in particular, the 2008 financial crisis. For example, considering the inability for existing economic theories to describe, to predict and to explain in a timely manner in the front of the recent financial turmoil, Paul Krugman commented as follows in *New York Times* (2009-09-02),

The economic profession went astray because economists, as a group, mistook beauty, clad in impressive-looking mathematics, for truth… As memories of the Depression faded, economists fell back in love with the old, idealized vision of an economy in which rational individuals interact in perfect markets… Unfortunately, this romanticized and sanitized vision of the economy led most economists to ignore… things that can go wrong. They turned a blind eye to the limitations of human rationality that often leads to bubbles and burst; to the problem of institutions that run amok; to the imperfection of markets… that can cause the economy… to undergo sudden, unpredictable crashes; and to the dangers created when regulators don't believe in regulation.

while Paul De Grauwe wrote the following in *Financial Times* (2009-07-21):

Mainstream (economic) models take the view that economic agents are superbly inform and understand the deep complexities of the world ... they have "rational expectations"… they all understand the same "truth", they all act the same way. Thus modelling the behavior of just one agent (the "representative" consumer and the "representative" producer) is all one has to do to fully describe the intricacies of the world. Rarely has such a ludicrous idea been taken so seriously by so many academics.

This paper aims at addressing the aforementioned question of fundamental importance by basing our reasoning and analysis on the four natural endowments of human beings: self-awareness, imagination, conscience and free will. To do this, we focus on the study of such general utility of an individual as an explicit function in the dollar value of total consumption, the number of hours spent on waged work and the person's particular system of values and beliefs. More specifically, the third variable is categorical and mostly not known to others and maybe in many cases even not known to the person him/herself involved. We examine the following values of this variable individually one by one:

(1) The system positively values the consumption of commodities while treating waged job negatively;

(2) The system believes in minimal commodity consumption, under which the following two subcases are detailed: (i) the individual maximally enjoys providing his labor on the waged work, and (ii) the person likes to supply as little labor as possible to his waged work; and

(3) The system demands for a non-standard method of optimization of the established utility function.

By basing our reasoning and analysis on the novel ground of natural human endowments, this paper establishes 11 formal propositions, some of which, among others, reveal how an individual's marginal utility of commodity consumption and that of working on waged work vary respectively with (i) the income from non-waged sources, (ii) the number of hours spent on waged work, (iii) hourly wage rate, (iv) additional savings, (v) unit commodity price, and (vi) expense on leisure. By comparing these results with each other, it can be readily seen that within different systems of values and beliefs, the identified utility function behaves differently. Most importantly, such comparison and several constructed examples collectively demonstrate that when an individual decides on how much commodity is to be consumed and how much labor output is to be supplied to his/her waged work by maximizing the corresponding utility subject to existing constraints, the individual's utility and his/her method of optimization are exclusively defined by his/her value-belief system. In other words, this paper contributes to the literature through supporting Simon's (1986) claim that the widely adopted rationality is about the decision behaviors of individuals and Rubinstein's (1998) belief that the selected option is most preferred among available alternatives, where preference is defined by the individual's natural endowments. This end differs majorly from the well-adopted definition of rationality – maximize an individual's advantage based on cost-and-benefit analysis (e.g., Friedman, 1953).

The rest of this paper is organized as follows. Section 2 examines how and why each individual has his/her own unique system of values and beliefs regarding how the world functions, what are considered either right or wrong and to what degree, and where the person is positioned in the myriad of things in the world. Section 3 looks at such a situation that a person's value-belief system positively values the consumption of commodities while seeing waged job negatively. Section 4 considers the scenario that an individual's value-belief system believes in minimal commodity consumption. Section 5 investigates scenarios involving non-standard optimizations of utilities that lead to the conclusion that both utility and method of optimization are exclusively determined by the value-belief system of the individual involved. Section 6 concludes this paper while pointing to potential future problems for research.

2. The Existence of Value-Belief Systems that Vary from one Person to Another

This section, which is mainly based on Forrest and Liu (2021) and Lin and Forrest (2012), prepares the background knowledge necessary in order for the logical reasoning of the rest of the paper to go through smoothly. It provides reasons for why each person has his/her own unique system of values and beliefs regarding how the world operates, what are considered morally right or wrong and to what degree, and where his/her being is positioned in the myriad of things in the world and in nature. Different from similar studies in social science (e.g., Carden et al., 2021; Churchland, 2019; Ekstrom, 2000; Gamsakhurdia, 2019), where data- or anecdote-based observations and conjectures are treated as confirmed conclusions, although only statistically for most cases (Forrest, 2018, p. 12-16), discussions in this section are based on the methodology and the holistic thinking of systems science (Forrest et al., 2013).

For the current purpose, let us imaginarily reason by starting from the moment when a person is bornin this physical world. For a period of time, this person lives within the boundaries of many constraints and has to passively submit to the caretaker and the restricted environment. The newborn baby, as an input-out system (Forrest, 2018), develops its simple beliefs, basic values, and fundamental philosophical assumptions from exchanges with people and limited exposure to the environment. For instance, the baby swiftly discovers that "everybody around must take care of me; otherwise he/she will have to bear with the consequence – my crying, really loud crying." In other words, the nature of being an input-output system, which exchanges with other entities, makes the baby aware that he/she exists as an individual and an entity that is different and separate from other people and objects, which is the person's endowment of self-awareness (Cooke, 1974; Lin and Forrest, 2012). So, the conclusion below follows:

The endowment of self-awareness helps a person examine either consciously or unconsciously his/her thoughts and how to respond adequately to circumstances.

By employing developed beliefs, values and assumptions, the child orders the caretaker and directs the surrounding environment to meet its various needs and desires. As the child grows older, he/she gradually uses his/her forever expanding collection of beliefs, values and assumptions to elucidate whatever unfathomable, develop tactics to overcome difficulties, and fashion ways to manage his/her own dealings and concerns.

Over time, the person's mental capacity increases in maturity so that he/she gains an increasing amount of control over his/her self-awareness. That strengthening mental capacity assists the person to acquire and master efficient tools and advanced knowledge from differentiated sources in the environment of a broadening scale and range. Therefore, the reservoir of experience and knowledge of the person's imagination (Egan, 1992; Lin and Forrest, 2012; Norman, 2000) concurrently grows with new elements continuously added either consciously or unconsciously, while the elements of the reservoir are associated with each other at rising levels to form intellectual understandings of things, events, thoughts and situations. These associations of experiences and knowledge grow more fortified within the person's self-consciousness. As soon as the strength of these associations goes beyond some threshold value, Bjerknes's (1898) Circulation Theorem guarantees that certain abstract, multi-dimensional eddy motions will appear within the self-awareness and the reservoir of that person's imagination. It is these abstract, multi-dimensional input-output movements of the experiences and knowledge that the person's imagination helps the person form his/her view of life, belief on how the world operates and philosophical system of values within the mind.

This holistic analysis in the previous paragraphs points to the following realization:

A person forms his/her unique view of life, belief of how the world operates, and philosophical values by closely associating experiences and knowledge that exist in the reservoir of his/her imagination.

Because there is not any such an environment into which more than one person is born, people's exchanges with their caretakers and environments are different from one person to another. These differences, which, for example, exist in family compositions, environmental structures, and interactions between and among entities in the environment, help people formulate their correspondingly different philosophical systems of values and beliefs. That is, we have the following conclusion:

Different people hold their individually varied views of life, beliefs of how the world operates and systems of values.

A person's conscience stands for such an ability that the person can use to know the principles by which his/her behaviors are judged as acceptable and to what degree his/her thoughts and actions are in accord with the principles (*Buss, 2004;* Pfaff, 2007; Tinbergen, 1951*)*. It is through these principles that a person is able to separate what's wrong from what's right, what is moral from what is not, making him/her feel remorse, morality or truthfulness accordingly. Regarding conscience, Forrest and Liu (2021, Proposition 10.9) establish the following systemic result

Each person is genetically endowed with a capability of conscience; and some of the elements in the reservoir of a person's imagination are assigned with either a morality + value or a – value.

Jointly, the analysis and discussion above indicate that although a person's capacity for conscience is genetically determined, the person's conscience resides totally on top of his/her imagination. While his/her imagination develops on top of the person's self-awareness – an innate capability of the person, the exact contents of the person's conscience and the assigned morality values are learned throughout the entire life span.

As for free will, it stands for such a capability by mobilizing that a person makes promises to others or him/herself. The capability helps a person make estimates regarding what he/she can do and what's optimal that can be carried out for resolving the issue at hand (Lin and Forrest, 2012). Implicitly, free will is an aptitude that helps people make decisions and pick choices among alternatives and correspondingly take consequent follow-through actions that materialize those choices and decisions.

The previous discussion indicates that as a person grows and matures over time, his/her reservoir of imagination enlarges continuously; and an increasing number of elements in the reservoir are assigned with morality values of either + or –. So, no matter whether or not the person is aware of his/her specific "self," there are three possibilities: (a) the "self" is assigned a + morality value; (b) the "self" is assigned a – morality value; or (3) the "self" is assigned with neither a + nor – morality value.

When possibility (a) holds true, the person makes promises based on estimates that are as accurate as possible so that what is promised can be mostly kept. If for a particular situation where a good estimate cannot be derived, the person will agree to do his/her best without providing any assurance of accomplishing the desired outcome. That is, for possibility (a), the person is able to keep what is promised. If possibility (b) turns out to be the case, then the person also determines as scrupulously as possible regarding the underlying potential so that he/she will most likely make promises that are opposite to what can be expectedly achieved. In other words, for possibility (b), promised is opposite to what will happen. And as for possibility (c), the person grew up without really knowing or caring whether his/her "self" means anything good or evil. Therefore, the person simply makes random promises (or noises) that are pleasant to the ear without considering to take correspondingly actions. No matter what happens next, it does not affect the person in any way conscientiously. Therefore, the following is concluded by Forrest and Liu (2021).

The endowment of free will assumes one of the following three possible scenarios: (i) promises are mostly kept; (ii) promised is most likely opposite to the actual outcome; and (iii) whatever is promised does not have anything to do with the outcome.

To further prepare, the rest of this paper looks at an individual who spends h hours working on a waged job or employment in the labor market. Assume that this individual's utility function U is real-valued and differentiable and is given as follows:

$$U = U(x, h, A), \tag{1}$$

where x stands for the individual's consumption of aggregate commodity, and A his/her personal system of values and beliefs. As in real life, A is a categorical variable and is not definitively known to other people. To show that values of A really make difference, this paper considers such A-value as

- A positively values the consumption of commodities, while seeing waged job negatively.
- A believes minimal commodity consumption. And
- A determines how uniquely the utility function of concern is optimized according to the value-belief system of the individual involved.

If w represents the constant hourly wage and y the income independent of the waged work. Then the individual's total income is given below:

$$\text{total income} = wh + y. \tag{2}$$

That is, the individual faces the optimization problem of maximizing his/her utility function in equation (1) subject to the budget constraint in equation (2) by choosing $x > 0$ and $h \geq 0$.

3. When Consumption is Preferred while Work is not Desirable

This section looks at such a system A of values and beliefs that the consumption of commodities is valued positively so that the more commodities are consumed, the better, while working on a waged job is seen negatively such that the less time is spent on the waged job, the better. This scenario is the one typically considered in the literature (e.g., Pencavel, 1986; Prescott, 2004). To reflect this scenario, let us impose the following conditions on the individual's utility function in equation (1):

$$\frac{\partial U}{\partial x} > 0, \frac{\partial U}{\partial h} < 0, \frac{\partial^2 U}{\partial x^2} < 0, \frac{\partial^2 U}{\partial h^2} < 0, \tag{3}$$

where the conditions on the second-order partial derivatives are employed to guarantee the necessary concavity of the utility function.

3.1 The Evolution of Marginal Utility Function

In this case, let p represent the fixed unit price of the aggregate commodity. Then the individual maximizes his/her utility function subject to the following budget constraint, assuming that no decision on saving is involved.

$$px = wh + y. \tag{4}$$

Using the method of Lagrange multipliers, the first-order condition of this constrained optimization problem is

$$\begin{bmatrix} \frac{\partial U}{\partial x} \\ \frac{\partial U}{\partial h} \end{bmatrix} = \lambda \begin{bmatrix} p \\ -w \end{bmatrix}, \tag{5}$$

where λ is the Lagrange multiplier.

Proposition 1. This individual's Lagrange multiplier λ is a positive function of income y that is independent from the waged work, the commodity price p, wage rate w, the consumption x of aggregate commodity and the labor supply h, satisfying that

$$\frac{\partial \lambda}{\partial y} < 0, \frac{\partial \lambda}{\partial w} \leq 0, \frac{\partial \lambda}{\partial h} < 0 \text{ and } \frac{\partial \lambda}{\partial p} \lesseqgtr 0. \tag{6}$$

Because λ is determined jointly by equations (2) and (5), it follows that λ is a function of all the variables mentioned in the proposition. And, from $\partial U/\partial x > 0$, as given in equation (3), and $\partial U/\partial x = \lambda p$, as indicated in equation (5), we know that λ takes positive values only. By solving equation (2) for x, we produce $x = (wh + y)/p$ and then the following:

$$\frac{\partial x}{\partial y} = \frac{1}{p} > 0, \frac{\partial x}{\partial w} = \frac{h}{p} \geq 0, \frac{\partial x}{\partial h} = \frac{w}{p} > 0, \frac{\partial x}{\partial p} = \frac{-(wh+y)}{p^2} < 0.$$

And by equating the first cells on both sides of equation (5), it follows that $\lambda = p^{-1} \cdot (\partial U/\partial x)$. So, from equation (1) we have

$$\frac{\partial \lambda}{\partial y} = \frac{1}{p} \cdot \frac{\partial^2 U}{\partial x^2} \cdot \frac{\partial x}{\partial y} = \frac{1}{p^2} \cdot \frac{\partial^2 U}{\partial x_t^2} < 0,$$

$$\frac{\partial \lambda}{\partial w} = \frac{1}{p} \cdot \frac{\partial^2 U}{\partial x^2} \cdot \frac{\partial x}{\partial w} = \frac{h}{p^2} \cdot \frac{\partial^2 U}{\partial x_t^2} \leq 0,$$

$$\frac{\partial \lambda}{\partial h} = \frac{1}{p} \cdot \frac{\partial^2 U}{\partial x^2} \cdot \frac{\partial x}{\partial h} = \frac{w}{p^2} \cdot \frac{\partial^2 U}{\partial x^2} < 0$$

and

$$\frac{\partial \lambda}{\partial p} = \frac{-1}{p^2} \cdot \frac{\partial U}{\partial x} + \frac{1}{p} \cdot \frac{\partial^2 U_t}{\partial x^2} \cdot \frac{\partial x}{\partial p} = \frac{-1}{p^2} \cdot \frac{\partial U}{\partial x} - \frac{wh+y}{p^3} \cdot \frac{\partial^2 U_t}{\partial x^2} \lesseqgtr 0$$

Hence, all inequalities in equation (6) are shown.

Proposition 2. The following hold true in general:

(i) The individual's marginal utility of commodity consumption decreases along with increasing income y that is independent from waged work; and

(ii) The individual's marginal utility from working extra hours on the waged work increases with increasing income y.

To see the first part of this statement, let y_1 and y_2 be two different values of y such that $y_1 < y_2$. Then, equation (6) implies that $\lambda|_{y=y_1} > \lambda|_{y=y_2}$. So, equation (5) indicates the following inequality, which shows the first part of statement (1) above:

$$\left.\frac{\partial U}{\partial x}\right|_{y=y_1} = \lambda|_{y=y_1} p > \left.\frac{\partial U}{\partial x}\right|_{y=y_2} = \lambda|_{y=y_2} p.$$

To see the second part of this statement, let y_1 and y_2 be two distinct amounts of income that are independent from the waged work, satisfying $y_1 < y_2$. Then, equation (6) implies that $\lambda|_{y=y_1} > \lambda|_{y=y_2}$. So, equation (5) indicates the following, which confirms the second part of statement (1) above:

$$\left.\frac{\partial U}{\partial h}\right|_{y=y_1} = -\lambda|_{y=y_1} w < \left.\frac{\partial U}{\partial h}\right|_{y=y_2} = -\lambda|_{y=y_2} w.$$

Proposition 3. If the individual supplies a positive amount of labor on the waged work, then the following hold true:

(i) The individual's marginal utility of commodity consumption drops along with increasing hourly rate of the waged work; and

(ii) The individual's marginal utility from working extra hours on the waged work increases along with increasing hourly rate of the waged work.

The argument for this conclusion is similar to that of Proposition 2. All details are omitted.

3.2 Reservation Hourly Wage and Unit Commodity Price

Dividing the second equation in equation (5), as obtained by equating corresponding cells from both sides of equation (5), by the first one produces

$$\frac{w}{p} = \text{real wage} = -\frac{\partial U/\partial h}{\partial U/\partial x} = -m(x,h,A), \tag{7}$$

where $-m(x,h,A)$ is the marginal rate of substitution of the working hours for the consumption of commodities. By solving equations (2) and (7) jointly for x and h, we obtain the functions of the optimizing demand x for commodities and the optimizing work-hour supply h as follows, if $h > 0$:

$$\begin{cases} x^{max} = x^{max}(p, w, y, A) \\ h^{max} = h^{max}(p, w, y, A) \end{cases} \tag{8}$$

The special hourly wage rate w^*, satisfying $w^*/p = -m(x, 0, A, \varepsilon)$, represents the implicit value of the individual's time at the given commodity price p, and the personal system A of values and beliefs. This wage rate w^* is known as the individual's reservation wage (Prescott, 2004) for the given p and A. That is, only when $-m(x, h, A) = w/p > -m(x, 0, A) = w^*/p$, the individual will participate in the labor market. Hence, we have

$$\forall w \in \mathbb{R}^+ \ni (w > w^* \rightarrow h > 0) \wedge (w \leq w^* \rightarrow h = 0), \tag{9}$$

where $\mathbb{R}^+$ stands for the set of all positive real numbers. In other words, the reservation hourly wage rate w^* determines whether or not the individual will be prepared to supply his labor to the market.

If by leisure we mean any activity that is not any part of the waged employment, then the previous analysis shows the following conclusion.

Proposition 4. Assume that an individual has an endowed block of available time that is split between either participating in waged work or enjoying leisure, and that he/she also receives income from at least one other source that is independent of his/her labor supply in the market, then the following hold true:

(i) For any given unit price p of the aggregate commodity and personal system A of values and beliefs, there is a reservation hourly wage rate w^* so that when the market hourly wage rate w of a job is greater than w^*, the individual will participate in the labor market; otherwise, he/she will not enter the labor market; and

(ii) For any chosen level of participation in the labor market and personal system A of values and beliefs, there is a reservation unit price p^* so that when the unit price p of the aggregate commodity is less than p^*, the individual's demand for the aggregate commodity is positive; otherwise, her demand will be non-existent.

Proposition 5. Let

$$V = U(x, h, A)|_{x=x^{max}, h=h^{max}} = V(p, w, y, A) \tag{10}$$

be the maximized utility of the individual. Then the maximum demand x^{max} for commodities and the maximum labor supply h^{max} are analytically given by the following formulas:

$$\begin{cases} x^{max}(p,w,y,A) = -\frac{\partial V/\partial p}{\partial V/\partial y} \\ h^{max}(p,w,y,A) = -\frac{\partial V/\partial w}{\partial V/\partial y} \end{cases} \tag{11}$$

In fact, applying the method of Lagrange multipliers to equation (10) and the budget constraint $xp = wh + y$ leads to

$$\begin{bmatrix} \frac{\partial V}{\partial p} \\ \frac{\partial V}{\partial w} \\ \frac{\partial V}{\partial y} \end{bmatrix} = \lambda \begin{bmatrix} -x \\ h \\ 1 \end{bmatrix},$$

where λ is the Lagrange multiplier, which, according to the third equation of above matrix expression, is equal to the marginal utility of the non-waged income y when the utility function is evaluated at its maximum. Through respectively dividing the first and the second equation by the third in the previous expression, we obtain equation (11).

Example 1. In this case, we use a specific utility function to confirm scenario (1) listed above. In particular, let the individual's utility function be:

$$U = 2x^{\frac{1}{2}} - \frac{1}{3}h^3. \tag{12}$$

Then, this utility function satisfies the inequalities in equation (3). Let $p = 1$, $w = 1$ and $y = 0$, equation (4) becomes $x = h$. So, the method of Lagrange multipliers implies $x^{-1/2} = h^2$. So, $x = h = 1$, and

$$U_{max} = \frac{5}{3} \approx 1.6667 \text{ and } \left.\frac{\partial U}{\partial x}\right|_{y=0} = 1. \tag{13}$$

Similarly, for $p = 1$, $w = 1$ and $y = 1$, equation (4) becomes $x = h + 1$. Equation $x^{-\frac{1}{2}} = h^2$ implies that $h^4(h + 1) = 1$ so that $h \approx 0.8566$ and $x \approx 1.8566$. Correspondingly, we have

$$U_{max} \approx 2.5156 \text{ and } \left.\frac{\partial U}{\partial x}\right|_{y=1} \approx 0.7339. \tag{14}$$

The marginal utility function values for $y = 0$ and $y = 1$ respectively in equations (13) and (14) confirm the conclusion in Proposition 2(i).

Similarly, for $p = w = 1$, we can obtain

$$\left.\frac{\partial U}{\partial h}\right|_{y=0} = -1, \left.\frac{\partial U}{\partial h}\right|_{y=1} \approx -0.7338,$$

where confirms the conclusion in Proposition 2(ii).

Let $p = w = 1$, $y = 0$, and respective, $p = 1, w = 2$, $y = 0$, we obtain

$$\left.\frac{\partial U}{\partial x}\right|_{w=1} = 1;\ \left.\frac{\partial U}{\partial x}\right|_{w=2} \approx 0.6600;\ \left.\frac{\partial U}{\partial h}\right|_{w=1} \approx -1.7411, \left.\frac{\partial U}{\partial h}\right|_{w=2} \approx -1.3195,$$

which confirm the conclusions in Proposition 3.

According to equation (7), the marginal rate of substitution of the working hours for the commodity consumption is given by

$$-m(x, h, A) = \frac{w}{p} = h^2 x^{-1/2}.$$

So, the reservation hourly wage $w^* = 0$ and the reservation unit commodity price $p^* = +\infty$. In other words, as indicated by Proposition 4, if the individual values commodity consumption and devalues labor output in the waged work, then

(i) For any given unit-commodity price p, as long as the hourly wage rate is positive, the individual will participate in the labor market; and

(ii) The individual's demand for commodity consumption is positive.

For the special case of $y = 0$, we produce:

$$\begin{cases} x^{max}(p, w, y, A) = \left(\frac{w}{p}\right)^{6/5} \\ h^{max}(p, w, y, A) = \left(\frac{w}{p}\right)^{1/5} \end{cases}$$

4. Two Scenarios when Commodity Consumption is Kept to Minimum

This section looks at such an individual that as dictated by his/her value-belief system A the person keeps his/her commodity consumption to the minimum level of basic survival. Under this condition, we study two scenarios respectively:

(1) The individual maximally enjoys providing his labor on the waged work. And

(2) The person also likes to supply as little labor as possible to his waged work.

4.1 Minimum Commodity Consumption with a Joyful Waged Work

To reflect Scenario (1), which describes the situation of a workaholic (van Beek et al., 2011), let us consider the following utility function along with the imposed conditions, where s stands for savings:

$$U = U(x, h, s, A), \text{satisfying } \frac{\partial U}{\partial x} < 0, \frac{\partial U}{\partial h} > 0, \frac{\partial^2 U}{\partial x^2} < 0, \frac{\partial^2 U}{\partial h^2} < 0. \tag{15}$$

The reason why we include savings in this utility function is because when the individual enjoys working while is not motivated to spend extra on commodities, he/she has to have a place to park the additional earnings. And as before, the conditions on the second-order partial derivatives in equation (15) are employed to guarantee the needed concavity of the utility function. At the same time, the fact that no condition in equation (15) is imposed on the variable s reflects that earning additional money does not play a role on the person's utility.

In this case, the budget constraint can be rewritten as

$$px + s = wh + y. \tag{16}$$

And the first order condition of this optimization problem is

$$\begin{bmatrix} \frac{\partial U}{\partial x} \\ \frac{\partial U}{\partial h} \\ \frac{\partial U}{\partial s} \end{bmatrix} = \lambda \begin{bmatrix} p \\ -w \\ 1 \end{bmatrix}, \tag{17}$$

where λ is the Lagrange multiplier.

Proposition 6. The following hold true:

(i) The individual's marginal utility of commodity consumption decreases along with increasing hourly wage rate w of the waged work;

(ii) The individual's marginal utility from working extra hours on the waged work increases along with increasing hourly wage rate w of the waged work; and

(iii) The individual's marginal utility from additional savings decreases along with increasing hourly wage rate w of the waged work.

To see the first part of this statement, the expression $\partial U/\partial x = \lambda p$ in equation (17) implies that $\lambda < 0$ due to equation (15). From equation (16), we have $\partial x/\partial w = hp^{-1} > 0$; and from equations (15), (16), (17), we obtain

$$\frac{\partial \lambda}{\partial w} = \frac{1}{p} \cdot \frac{\partial^2 u}{\partial x^2} \cdot \frac{\partial x}{\partial w} = \frac{h}{p^2} \cdot \frac{\partial^2 u}{\partial x^2} < 0.$$

That is, λ is a decreasing function in w. So, for $w_1, w_2 > 0$, condition $w_1 < w_2$ implies $\lambda|_{w=w_1} > \lambda|_{w=w_2}$. So, from equation (17), it follows that

$$\left.\frac{\partial U}{\partial x}\right|_{w=w_1} = \lambda|_{w=w_1} p > \left.\frac{\partial U}{\partial x}\right|_{w=w_2} = \lambda|_{w=w} p,$$

which shows the first part of this proposition.

To see the second part of this statement, the previous argument indicates that λ is a decreasing function in w. So, for $w_1, w_2 > 0$, satisfying $w_1 < w_2$, we have $\lambda|_{w=w_1} > \lambda|_{w=w_2}$. So, from equation (17), it follows that

$$\left.\frac{\partial U}{\partial h}\right|_{w=w_1} = -\lambda|_{w=w_1} w < \left.\frac{\partial U}{\partial h}\right|_{w=w_2} = -\lambda|_{w=w_2} w,$$

which shows the second part of this proposition.

To confirm the third part of this statement, the previous argument implies that λ is a decreasing function in w. So, for $w_1, w_2 > 0$, satisfying $w_1 < w_2$, we have $\lambda|_{w=w_1} > \lambda|_{w=w_2}$. So, from equation (17), it follows that

$$\left.\frac{\partial U}{\partial s}\right|_{w=w_1} = \lambda|_{w=w_1} > \left.\frac{\partial U}{\partial s}\right|_{w=w_2} = \lambda|_{w=w_2},$$

which shows the third part of this proposition.

Proposition 7. The following hold true:

(i) The individual's marginal utility of commodity consumption drops along with increasing income y that is independent from the waged work;

(ii) The individual's marginal utility from working extra hours on the waged work increases long with increasing income y; and

(iii) The individual's marginal utility from additional saving decreases long with increasing income y.

To see the first part of this statement, from equation (16), it follows that $\partial x/\partial y = p^{-1} > 0$. Equations (15), (16), (17) imply that

$$\frac{\partial \lambda}{\partial y} = \frac{1}{p} \cdot \frac{\partial^2 u}{\partial x^2} \cdot \frac{\partial x}{\partial y} = \frac{1}{p^2} \cdot \frac{\partial^2 u}{\partial x^2} < 0.$$

Hence, λ is a decreasing function in y. So, for $y_1, y_2 > 0$, satisfying $y_1 < y_2$, we have $\lambda|_{y=y_1} > \lambda|_{y=y_2}$. So, from equation (17), it follows that

$$\left.\frac{\partial U}{\partial x}\right|_{y=y_1} = \lambda|_{y=y_1} p > \left.\frac{\partial U}{\partial x}\right|_{y=y_2} = \lambda|_{y=y_2} p,$$

which confirms the first conclusion of this proposition.

To see the second part of this statement, let $y_1, y_2 > 0$, satisfying $y_1 < y_2$, we have $\lambda|_{y=y_1} > \lambda|_{y=y_2}$. So, from equation (17), it follows that

$$\left.\frac{\partial U}{\partial h}\right|_{y=y_1} = -\lambda|_{y=y_1} w < \left.\frac{\partial U}{\partial h}\right|_{y=y_2} = -\lambda|_{y=y_2} w,$$

which shows the second part of this proposition. The third part of this statement follows the same argument as the one in the argument of the previous proposition.

From equation (17), it follows that

$$\frac{\partial U}{\partial x} \Big/ \frac{\partial U}{\partial s} = p, \frac{\partial U}{\partial h} \Big/ \frac{\partial U}{\partial s} = -w. \tag{18}$$

Solving the system of equations (16) and (18) for x, y and s produces

$$\begin{cases} x^{opt} = x^{opt}(p, w, y, A) \\ h^{opt} = h^{opt}(p, w, y, A) \\ s^{opt} = s^{opt}(p, w, y, A) \end{cases} \tag{19}$$

Let $V^{opt} = U(x^{opt}, h^{opt}, s^{opt}, A) = V^{opt}(p, w, y, A)$ be the maximized utility of the individual. Then the method of Lagrange multipliers implies that

$$\left\{ \begin{bmatrix} \frac{\partial V^{opt}}{\partial p} \\ \frac{\partial V^{opt}}{\partial w} \\ \frac{\partial V^{opt}}{\partial y} \\ \frac{\partial V^{opt}}{\partial s} \end{bmatrix} = \lambda \begin{bmatrix} x \\ -h \\ -1 \\ 1 \end{bmatrix} \right. . \tag{20}$$

Dividing respectively the first equating cells by the third one and fourth one in equation (20), dividing the second equating cells by the third and the fourth one, and applying equation (16) lead to the following result.

Proposition 8. The optimal demand x^{opt} for commodities, the optimal labor supply h^{opt} and the optimal savings x^{opt} are analytically given by the following formulas:

$$\begin{cases} x^{opt}(p, w, y, A) = -\frac{\partial V^{opt}/\partial p}{\partial V^{opt}/\partial y} = \frac{\partial V^{opt}/\partial p}{\partial V^{opt}/\partial s} \\ h^{opt}(p, w, y, A) = -\frac{\partial V^{opt}/\partial w}{\partial V^{opt}/\partial s} = \frac{\partial V^{opt}/\partial w}{\partial V^{opt}/\partial y} \\ s^{opt}(p, w, y, A) = wh^{opt} + y - px^{opt} \end{cases} . \tag{21}$$

Example 2. For the second scenario considered in the previous sections, where commodity consumption is kept at the minimum for basic survival, while the waged work is enjoyable so that more labor is pleasantly supplied to the work, let us specify individual's utility function be:

$$U = 2h^{\frac{1}{2}} - \frac{1}{3}x^3 + s^2, \tag{22}$$

where the first two terms on the right-hand side are the same as those in equation (12) except that the places of the variables x and h are switched. It is straightforward to check that all the inequalities in equation (15) are satisfied.

The method of Lagrange multipliers implies that

$$\frac{\partial U}{\partial x} = -x^2 = \lambda p, \frac{\partial U}{\partial h} = h^{-1/2} = -\lambda w, \frac{\partial U}{\partial s} = 2s = \lambda, \tag{23}$$

where λ is the Lagrange multiplier. So, we have

$$\frac{x^2}{h^{-1/2}} = \frac{p}{w}. \tag{24}$$

To double check Proposition 6, we first let $p = w = 1$ and $y = 0$. Then the budget constraint in equation (16) becomes $x + s = h$. So, equation (24) can be rewritten as $x^2 = h^{-1/2} = (x + s)^{-1/2}$. Respectively, if we let $p = 1, w = 2$ and $y = 0$, then we have $x^2 = h^{-1/2} = [(x + s)/2]^{-1/2}$. Therefore, the following is readily obtained

$$\left.\frac{\partial U}{\partial x}\right|_{w=1} = \frac{-1}{\sqrt{x+2}} > \frac{-1}{\sqrt{(x+2)/2}} = \left.\frac{\partial U}{\partial x}\right|_{w=2}.$$

This end confirms the conclusion in Proposition 6(i). And, similarly, we obtain from equation (23)

$$\left.\frac{\partial U}{\partial h}\right|_{w=1} = \frac{1}{\sqrt{x+2}} < \frac{1}{\sqrt{(x+2)/2}} = \left.\frac{\partial U}{\partial h}\right|_{w=2},$$

which confirms the conclusion in Proposition 6(ii). Next, equation (23) implies that $\partial U/\partial s = -w^{-1}\,\partial U/\partial h$ and therefore

$$\left.\frac{\partial U}{\partial s}\right|_{w=1} = -\left.\frac{\partial U}{\partial h}\right|_{w=1} > -\left.\frac{\partial U}{\partial h}\right|_{w=2} > \frac{-1}{2}\left.\frac{\partial U}{\partial h}\right|_{w=2} = \left.\frac{\partial U}{\partial s}\right|_{w=2},$$

which confirms the conclusion in Proposition 6(iii). By letting $p = w = 1$, we obtain

$$\frac{\partial U}{\partial x} = -(h + y - s)^2, \frac{\partial U}{\partial h} = \frac{w}{p}(h + y - s)^2, \frac{\partial U}{\partial s} = \frac{-1}{p}(h + y - s)^2.$$

So, conclusions in Proposition 7 are confirmed.

4.2 Minimum Commodity Consumption with as Little Labor Supply as Possible

Regarding scenario (2), as listed at the beginning of this section, that the individual of concern does not enjoy the consumption of commodities and likes to supply as little labor as possible to any waged work. Additionally, assume that the person needs to maintain the minimum level of commodity consumption for basic survival. To this end, he/she also need to supply labor, although as little as possible, to a waged work in order to meet the minimum financial requirement to survive. What this scenario describes very well matches the phenomenon of hikikomori in Japan (Bowker et al., 2019). To study this current scenario, let us impose the following conditions on the individual's utility function in equation (1): There are $x_{min} > 0$ and $h_{min} \geq 0$ such that

$$\begin{aligned} &\frac{\partial U}{\partial x} \geq 0, \frac{\partial U}{\partial h} \geq 0, \text{for } 0 \leq x \leq x_{min}, 0 \leq h \leq h_{min}, \\ &\frac{\partial U}{\partial x} < 0, \frac{\partial U}{\partial h} < 0, \text{for } x > x_{min}, h > h_{min}, \\ &\frac{\partial^2 U}{\partial x^2} < 0, \frac{\partial^2 U}{\partial h^2} < 0. \end{aligned} \tag{25}$$

Such a scenario appears when the individual is addicted to one or several activities he participates in during his leisure time. Assume that the person spends q dollars on his leisure activities. Hence, the budget constraint for this individual is

$$px + q = wh + y. \tag{26}$$

Proposition 9. The following hold true:

(i) The individual's marginal utility of commodity consumption is a non-increasing function in the hourly wage rate w of the waged work; and
(ii) The individual's marginal utility from working extra hours on the waged work is a non-decreasing function in the hourly wage rate w of the waged work.

The proof is similar to those of parts (i) and (ii) in Proposition 6. All relevant details are omitted.

Proposition 10. The following hold true:

(i) The individual's marginal utility of commodity consumption drops along with increasing income y that is independent from the waged work;
(ii) The individual's marginal utility from working extra hours on the waged work increases long with increasing income y;

(iii) The individual's marginal utility of commodity consumption increases along with increasing unit commodity price p, for when the commodity consumption x is greater than the minimum x_{min};
(iv) The individual's marginal utility from working extra hours on the waged work decreases with increasing p, for when the commodity consumption x is greater than the minimum x_{min};
(v) The individual's marginal utility of commodity consumption increases along with increasing expense q on leisure; and
(vi) The individual's marginal utility from working extra hours on the waged work decreases with increasing expense q.

The proof for (i) and (ii) is the same as that of Proposition 7. For (iii), the method of Lagrange multipliers implies that $\partial U/\partial x = \lambda p$; and from equation (26) it follows that $\partial x/\partial p = -(wh + y - q)/p^2 \leq 0$. Hence, we have the following for $x > x_{min}$

$$\frac{\partial \lambda}{\partial p} = \frac{\partial}{\partial p}\left(\frac{1}{p}\frac{\partial U}{\partial x}\right) = -\frac{1}{p^2}\frac{\partial U}{\partial x} + \frac{1}{p}\frac{\partial^2 U}{\partial x^2}\frac{\partial x}{\partial p} = -\frac{1}{p^2}\frac{\partial U}{\partial x} - \frac{(wh+y-q)}{p^3}\frac{\partial^2 U}{\partial x^2} > 0,$$

because equation (25) implies that $-p^{-2} \cdot \partial U/\partial x > 0$ for $x > x_{min}$, while $-(wh + y - q)p^{-3} \cdot \partial^2 U/\partial x^2 \geq 0$, assuming that the individual does not live on borrowed money. That is, for $x > x_{min}$, λ is an increasing function in p. So, for any p_1 and p_2, satisfying $p_1 < p_2$, we have $\lambda|_{p=p_1} < \lambda|_{p=p_2}$ so that

$$\left.\frac{\partial U}{\partial x}\right|_{p=p_1} = \lambda|_{p=p_1} \cdot p_1 < \lambda|_{p=p_2} \cdot p_2 = \left.\frac{\partial U}{\partial x}\right|_{p=p_2}.$$

This end confirms the conclusion in (iii). The proof for (iv) follows from $\lambda|_{p=p_1} < \lambda|_{p=p_2}$ and $\partial U/\partial h = -\lambda w$. All details can be filled in as above and are omitted. Similarly, parts (v) and (vi) can be shown.

Example 3. For the third scenario considered in the previous paragraphs, where the commodity consumption is kept at the minimum for basic survival, and as little labor as possible is supplied to the waged work, let us specify individual's utility function as follows:

$$U = -(x-2)^2 - (h-3)^2, \tag{27}$$

so that the inequalities in equation (25) are satisfied with $x_{min} = 2$ and $h_{min} = 3$. This negative utility function means that the individual wants to minimize the adverse impact of labored work and commodity consumption.

By using the method of Lagrange multipliers and budget constraint in equation (2), we can produce

$$\frac{\partial U}{\partial x} = \frac{2p}{w}\left(\frac{px+q-y}{w} - 3\right) \text{ and } \frac{\partial U}{\partial h} = -2\left(\frac{px+q-y}{w} - 3\right). \quad (28)$$

So, the conclusions in Propositions 9 and 10 are confirmed.

5. WHEN MAXIMIZATION TAKES ON A DIFFERENT MEANING

The previous two sections consider three scenarios where the value-belief system A of the individual of concern specifies respectively: (1) more commodity consumption is better, while less labor supply to the waged work is more desirable; (2) commodity consumption is kept at the minimum for basic survival, while the waged work is enjoyable so that more labor is pleasantly supplied to the work; and (3) commodity consumption is kept at the minimum for basic survival, and as little labor as possible is supplied to the waged work. And for each of these cases, the specified scenario can be adequately described as a standard optimization problem with correspondingly varied constraints. Different from the previous discussions, this section looks at such a particular value-belief system A that the output values of the objective function are not ordered as how real numbers are ordered ordinarily.

In particular, let $\mathbb{R}$ be the set of all real numbers and a a positive real number. We define a linear order relation $<_{mod(a)}$ on $\mathbb{R}$ as follows: For any x and $y \in \mathbb{R}$,

$$x <_{mod(a)} y \text{ if and only if } x\, mod(a) < y\, mod(a), \quad (29)$$

where the ordering $<$ is the conventional one defined on $\mathbb{R}$, $x\, mod(a)$ is the remainder of $x \div a$ and $y\, mod(a)$ the remainder of $y \div a$, such that $|x\, mod(a)| < a$ and $|y\, mod(a)| < a$. When all the involved numbers a, x and y are integers, this order relation $<_{mod(a)}$ degenerate into the one widely studied in number theory (Burton, 2012).

Geometrically, this mod function transforms the real number line $\mathbb{R}$ into a "spring" of infinite length, Figure 1, so that for any positive $r \in \mathbb{R}$, satisfying $0 \leq r < a$, the following set of real numbers are classified into one equivalence class:

$$\{x \in \mathbb{R}: \exists q \in \mathbb{Z}(x = aq + r)\}, \quad (30)$$

where $\mathbb{Z}$ stands for the set of all whole numbers, that is, $\mathbb{Z} = \{\dots, -3, -2, -1, 0, +1, +2, +3, \dots\}$. The arrows in Figure 1 signal the positive direction with the opposite being the negative direction. All such numbers as 0,

$\pm a, \pm 2a, \pm 3a, \ldots$, are identified as equivalent with 0 serving as the representative of the equivalence class. By doing so in general, the class given in equation (30) can be represented by $r \in [0, a)$. For example, when $a = 2$, because 2.1 = $1 \cdot 2 + 0.1$ and $-2.1 = (-3) \cdot 2 + 0.9$, 2.1 is equivalent to and is represented by 0.1, while -2.1 is equivalent to and is represented by 0.9.

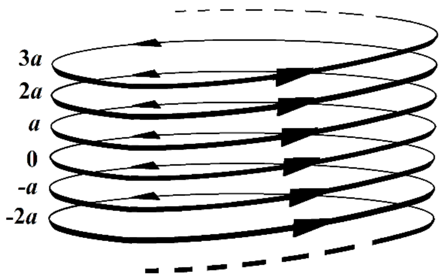

Figure 1 How the mod function turns the real number line into a "spring"

With the geometry of the mod function explained, the linear order relation $<_{mod(a)}$, as defined in equation (29), means the following: for any x and $y \in \mathbb{R}$, $x <_{mod(a)} y$, if and only if $r_x < r_y$, where r_x and $r_y \in [0, a)$ are respectively the representatives of x and y. Next, we look at how this order relation $<_{mod(a)}$ makes a difference for the case studied in Example 1 above.

Example 4. First, the maximization problem in Example 1, where the budge constraint is specified as $x = h$, provides the following outcomes:

$$max_{x,h} U = \frac{5}{3} \approx 1.667, x_{max} = h_{max} = 1. \quad (31)$$

If we consider this maximization problem by respectively introducing mod(2), mod(1.5) and mod(1), then the case of mod(2) provides the same solution as that in equation (31). However, for the case of mod(1.5), the maximization problem can be rewritten as follows:

$$max_{x,h}\left(U\, mod(1.5)\right) = \left(2x^{1/2} - \frac{1}{3}h^3\right) mod(1.5), \text{subject to } x = h,$$

then the solution becomes

$$max_{x,h}\left(U\, mod(1.5)\right) = 1.5, x_{max} = h_{max} \approx 0.62527,$$

where for $x = y = 1$, $U\, mod(1.5) = \frac{5}{3} mod(1.5) \approx 0.167$. That is, equation (31) is no longer the desired the solution.

As for the case of mod(1), the maximization problem becomes

$$max_{x,h}\left(U\,mod(1)\right) = \left(2x^{1/2} - \frac{1}{3}h^3\right) mod(1), \text{subject to } x = h.$$

So, the solution to this optimization problem is

$$max_{x,h}\left(U\,mod(1)\right) = \left(\frac{5}{3}\right)^{-} mod(1) \approx 0.667, x_{max} = h_{max} = 1^{-}.$$

where for any real number x, the symbol x^{-} stands for $\lim_{z \to x^{-}} z$. That is, equation (31) is no longer the desired the solution.

One take-away we can learn from Example 4 is that when the set of all possible values of the objective function is ordered in a specific way, the method employed to optimize the objective function must be accordingly adjusted. By combining the conclusions established above, we have

Proposition 11. If an individual's decision about the amount of commodity consumption and labor output into a waged work is made by optimizing his/her corresponding utility subject to the underlying constraints, then both the utility and method of optimization are exclusively defined by the individual's value-belief system.

6. Conclusion

By setting foot on the four natural human endowments – self-awareness, imagination, conscience and free will (Forrest and Liu, 2021; Lin and Forrest, 2012), this paper innovatively shows how an individual's utility and his/her method of optimization are fundamentally determined by the person's natural endowments. Therefore, our answer to the question, as posed in the beginning of this paper, of whether or not an economic man really relies on rationality to make consumption decisions is both yes and no. The yes answer comes from that the endowment of conscience, together with that of imagination, determines what is considered satisfactory (beyond what is morally right or wrong) (Section 2). And, the no answer stems from the conclusion implicitly established in this paper that each utility function is subjectively introduced by the decision maker, while the consequent optimization of the utility is dictated by criteria formulated within the person's system of values and beliefs. In particular, the literature (Hudik, 2019) tends to have the researcher, whoever he/she is, define utility functions and determine which method of optimization to use under the implicit assumption that he/she knows the decision maker well although in real life a person's value-belief system is not known anybody, including possibly the person him/herself. That is, the researcher represents the authority who decides which variables to include in a utility function and which specific method of optimization to use, although he/she has no idea about the underlying value-belief system of the decision maker. In the contrary, results developed in this paper clearly demonstrate that both a utility function and consequent method of optimization are determined either consciously or unconsciously by the specific individual involved in a decision situation. That is, when facing a decision situation, different people rely on different utility functions to choose their individually varied courses of actions. That explains in real life why the optimal course of action (or selection) in one person's eyes generally does not seem like optimal at all in another person's eyes.

Beyond the discussion in the previous paragraph, another major contribution this paper makes to the existent literature is that it relies on pure logical, systemic and analytical reasonings to derive conclusions without employing any empirically confirmed hypothesis as the basis and starting point of reasoning. Because of this reason, our developed conclusions are more theoretically sound than most of those that are data- or anecdote-based in the literature (Forrest and Liu, 2021).

For possible future research, one can investigate properties of marginal utilities under different circumstances of value-belief systems beyond the ones considered in this paper. Similarly, additional methods of optimization should be carefully introduced and studied. Another important scenario for future research is the question of what happens when an individual's decision is not derived on the optimization of any underlying objective function. Our expectation is that the same as what has been obtained in this paper – the person's utility and his/her method of optimization are exclusively defined by his/her value-belief system – will still be the result.

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