A Theory of Narrow Thinking*

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Abstract

Unlike in standard models, decision makers often "narrowly bracket" and make each decision in isolation. I develop a new approach, which I term *narrow thinking*, to systematically model narrow bracketing. The definition of narrow thinking is that different decisions are based on different, non-nested, information. As a result, the narrow thinker makes each decision with imperfect knowledge of other decisions and faces difficulties coordinating her multiple decisions. The narrow thinker effectively cares less about her other decisions when making each decision. The main application of narrow thinking is to provide a "smooth" model of mental accounting without requiring the decision maker to have explicit budgets. My approach generates unique predictions about how the degree of mental accounting depends on expenditure shares and cognitive limitations. It also illustrates how narrow bracketing and mental accounting can be explained by the same underlying friction.

Keywords: bounded rationality, narrow bracketing, incomplete information, multiple selves, mental accounting

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1 Introduction

Each decision maker faces multiple economic decisions. Research in psychology and behavioral economics shows that the decision maker often "narrowly brackets" and makes each decision in isolation (Tversky and Kahneman, 1981; Read, Loewenstein and Rabin, 1999). In standard modeling practice, however, we implicitly assume that the decision maker "broadly brackets" and can perfectly coordinate her multiple decisions. Consider the standard textbook consumer problem of demanding multiple goods. The classical demand function is derived imposing that, when the consumer purchases one good, she fully incorporates the impact of her other consumption. It is as if the decision maker makes all her consumption decisions together and perfectly coordinates them.

Notion of narrow thinking. In this paper, I develop a new approach to model narrow bracketing, which I term *narrow thinking*. Instead of directly imposing that each decision is made in isolation (Rabin and Weizsacker, 2009), the theory is based on a different notion: different decisions are based on *different*, non-nested, information. This notion is motivated by the psychological observation that the decision maker may not incorporate all relevant information when making each decision (Kahneman, 2011). For example, narrow thinking can arise because of bounded recall, selective retrieval from memory, and noisy perception (Anderson, 2009; Kahana, 2012; Bordalo, Gennaioli and Shleifer, 2020; Woodford, 2020).

As an example of such a narrow thinker, consider the following consumer. When she purchases food, she knows the food price, but does not have the gasoline price at the front of her mind. When she purchases gasoline, she knows the gasoline price, but does not have the food price at the front of her mind. Because her two consumption decisions are based on different, non-nested, information, this decision maker is a narrow thinker. As explained shortly, this narrow thinker faces difficulty in coordinating her decisions.

More abstractly, consider the following general multiple-decision problem. The decision maker's utility, $u\left(x_1, \cdots, x_N, \vec{\theta}\right)$, depends on her N decisions $\{x_i\}_{i=1}^N$ and the fundamental $\vec{\theta}$. Under narrow thinking, the decision maker is subject to a decision-specific information constraint: each decision x_i needs to be a function of the decision-specific (potentially multi-dimensional) signal s_i, which captures the decision maker's state of mind when she decides on x_i. The decision maker can then be thought of as a team of multiple selves (Marschak and Radner, 1972). Each self is in charge of one decision, but different selves do not perfectly share their information.

I recast the decision problem under narrow thinking as multiple selves playing an *incomplete-information*, common interest game. In the equilibrium of the game, since each self does not perfectly know other selves' signals (states of mind), each self's decision is made with imperfect knowledge of other selves' decisions. In this sense, narrow thinking introduces intra-personal frictions in coordinating multiple decisions.

A simple example: narrow thinking as a model of narrow bracketing. I start with a simple consumer theory example to illustrate how narrow thinking effectively attenuates the interaction across decisions and provides a model of narrow bracketing.

In this example, the consumer's utility is quasi-linear and the interaction between the two consumption decisions comes from the complementarity/substitutability embedded in the utility function (second-order cross-derivatives of the utility function). Each self $i \in \{1, 2\}$ of the narrow thinker perfectly knows the price of the good she buys p_i, but only receives a noisy signal about the other price.

The main question of interest is how the narrow thinker's consumption responds to price changes, i.e., the price elasticity of demand. Consider a shock to the price p_i. The response of consumption x_i can be decomposed into two parts. The first part captures the direct effect of p_i, holding the other consumption x_{-i} fixed. Since each self i of the narrow thinker perfectly knows p_i, this direct effect is the same as in the standard consumer theory. The second part captures the indirect effect from the response of the other consumption x_{-i}. Under narrow thinking, since the other self $-i$ does not perfectly know p_i, the coordinated response of x_{-i} is limited, and the indirect effect is dampened.

Narrow thinking implies complete narrow bracketing in the limit case when each self's signal about the other price is infinitely noisy. In this case, x_{-i} does not respond to shocks to p_i. As a result, the indirect effect from the response of x_{-i} is completely muted. The narrow thinker's demand for x_i is then the same as that of a decision maker who completely neglects the other decision, i.e., complete narrow bracketing.

Away from the limit, narrow thinking provides a *smooth* model of narrow bracketing: the response of consumption x_i to p_i can be written as a weighted average of the standard consumer theory response and the complete narrow bracketing response. This is because, away from the limit, the indirect effect driven by the coordinated response of x_{-i} to p_i is dampened but not completely muted. This smooth model is different from the existing models of narrow bracketing (Barberis, Huang and Thaler, 2006; Rabin and Weizsacker, 2009), which directly impose that the decision maker makes each decision in isolation.

Since narrow thinking arises when different decisions are made based on different information, narrow thinking generates a natural testable prediction: if the decision maker makes each consumption decision separately based on different states of mind, she narrowly brackets more; if the decision maker makes multiple decisions together based on the same state of mind, she narrowly brackets less. This prediction is consistent with the notion of "cognitive inertia" in Read, Loewenstein and Rabin (1999) and evidence in Redelmeier and Tversky (1992).

The main application: a smooth model of mental accounting. The main application of narrow thinking is to provide a smooth model of mental accounting. The existing formalization of mental accounting often centers around explicit budgets (Heath and Soll, 1996). That is, the decision maker allocates a fixed budget to each good or spending category by assumption. My approach, however, does not require these explicit budgets. It instead derives mental accounting behavior from the intra-personal difficulty in coordinating one's multiple decisions.

Specifically, since the discussion about mental accounting is inherently connected to the budget constraint (Thaler, 1985, 1999), I study the non-quasi-linear consumer theory case where interaction across different decisions comes from the budget constraint. I show how narrow thinking leads to "smooth" mental accounting: the narrow thinker's demand elasticity is a weighted average of the standard consumer theory elasticity and the explicit mental budgeting elasticity. Even though a narrow thinker does not have explicit budgets, since she has difficulty coordinating her decisions, her demand elasticity is closer to the explicit mental budgeting model, where each decision can be made in isolation.

The narrow thinking approach to mental accounting also leads to unique predictions about what drives the degree of mental accounting behavior. For example, a larger expenditure share for a good leads to a larger degree of mental accounting. Moreover, my approach illustrates how narrow bracketing and mental accounting can be explained by the same underlying friction, i.e., narrow thinking. In the literature, those two phenomena are sometimes loosely connected (Read, Loewenstein and Rabin, 1999; Thaler, 1999), but require different models.

A general principle: under-reaction or over-reaction. Depending on the environment, narrow thinking can translate into either under- or over-reaction relative to the frictionless benchmark. I introduce a general principle that helps predict whether the narrow thinker over- or under-reacts in a given environment. Similar to the simple example above, I first decompose each self's optimal decision into two parts: the direct effect, driven by the movement of the fundamental while holding other decisions fixed; and the indirect effect, driven by the coordinated response of other decisions. When the indirect effect works in the same direction as the direct effect, a dampening of the indirect effect under narrow thinking leads to under-reaction. When the indirect effect works in the opposite direction to the direct effect, a dampening of the indirect effect under narrow thinking leads to over-reaction.

Let me use a mental-accounting type behavior, excess sensitivity to own-price shocks (Hastings and Shapiro, 2013), as an example to illustrate this principle. Consider an increase in the food price. It has a negative direct effect on food consumption. But there is an opposite, positive, indirect effect on food consumption: the decision maker can decrease other consumption to smooth out the drop in food consumption. Under narrow thinking, however, the indirect effect from the coordinated decrease of other consumption is dampened and food consumption will decrease more. This general principle can also be used to explain other mental-accounting type behavior: under-reaction to taste shocks (Heath and Soll, 1996), the label effect (Abeler and Marklein, 2016), and the small wage elasticity of labor supply (Camerer et al., 1997).

Additional applications and extensions. I also study how narrow thinking can help explain two other types of narrow bracketing behavior: the neglect of "adding-up" effects (Read, Loewenstein and Rabin, 1999) and myopic loss aversion (Barberis, Huang and Thaler, 2006). Finally, I provide a framework to endogeneize narrow thinking: in this problem, besides making multiple decisions, the decision maker also chooses what information each decision is based upon, subject to a cognitive cost. Since different decisions are based on different decision rules, each self is "interested in" different parts of the fundamental. For example, in the simple consumer theory example above, each self wants to know more about the price of the good she buys. In this sense, narrow thinking arises endogenously.

Related literature. The narrow thinking approach builds upon the rational inattention literature (e.g., Sims, 2003; Mackowiak and Wiederholt, 2009; Matejka and McKay, 2015; Mackowiak, Matejka and Wiederholt, 2018) by using noisy signals to capture the decision maker's inability to incorporate all relevant information when making each decision. But there is a key difference. For static multiple-decision problems such as the demand for multiple goods (e.g., Koszegi and Matejka, 2020), the rational inattention approach lets different decisions be based on the *same*, imperfect, information.[1] The key friction is the decision maker's imperfect perception of the fundamentals. Each decision is nevertheless made with perfect knowledge about other decisions. By contrast, the narrow thinker's different decisions are based on *different*, non-nested, information. Each decision is then made with an imperfect understanding of other decisions. In fact, a key contribution of my paper is to show that limited information, seemingly separate from narrow bracketing, can provide a smooth model of narrow bracketing and explain related phenomena such as mental accounting.

Gabaix (2014, 2019) develops a "sparsity" method to model the decision maker's imperfect perception of the fundamentals. Similar to rational inattention, the sparse agent's multiple decisions are made based on the *same,* imprecise, perception of the fundamental.[2] For example, when purchasing food, a sparse agent may perfectly know the food price but have imperfect knowledge about the gasoline price. But this means that, when purchasing gasoline, this agent still perfectly

[1] When applying the rational inattention approach to dynamic problems (e.g., Steiner, Stewart and Matejka, 2017; Hébert and Woodford, 2019), similar to the standard sequential decision problem, the typical assumption is that the information of the earlier decision is perfectly nested in the information of the later decision. On the other hand, the narrow thinker's different decisions are based on different, *non-nested*, information.

[2] Gabaix (2014)'s sparsity approach does not use noisy signals. The perception of the fundamentals there is imperfect but deterministic.

knows the food price and has imperfect knowledge about the gasoline price. This is different from the narrow thinker studied here. In an extension of Gabaix (2014, 2017), the author also studies a "schizophrenic agent," whose different decisions are based on different perceptions of the fundamentals. My paper shows that this friction can lead to the decision maker's difficulty in coordinating her decisions, and provide a "smooth" model of narrow bracketing and mental accounting.

Hastings and Shapiro (2013), Hastings and Shapiro (2018), and Farhi and Gabaix (2020) provide a different smooth model of mental accounting. Their approach extends the explicit budgeting model by allowing the consumer to deviate from the mental budget subject to a cost. My approach makes progress by establishing the connection between mental accounting and narrow bracketing and generating unique predictions on what influences the degree of mental accounting behavior. Moreover, by dispensing with explicit mental budgets, I avoid taking a stand on where the budget comes from.

Bounded recall provides a psychological justification for why the narrow thinker's different decisions are made based on different, non-nested, information (e.g., Kahana, 2012; Wilson, 2014; Azeredo da Silveira and Woodford, 2019). My paper further studies how this friction leads to the decision maker's difficulty in coordinating her multiple decisions. Gennaioli and Shleifer (2010) use representativeness heuristics to model what comes to the decision maker's mind in single-decision problems. Bordalo, Gennaioli and Shleifer (2020) provide a similarity-based model of bounded recall.

Methodologically, I show that one can use the economic theoretical tools developed for *inter*-personal coordination frictions to study *intra*-personal decisions, and provide a new model of bounded rationality. I achieve this methodological goal by showing the equivalence between the decision problem under narrow thinking and the incomplete information game among multiple selves. A key insight from the existing literature is that incomplete information can attenuate the equilibrium interaction across different agents (Angeletos and Lian, 2017, 2018; Bergemann, Heumann and Morris, 2017). Within the context of single-agent, multiple-decision problems studied in this paper, this friction translates into effective attention of interaction across decisions and a model of narrow bracketing. My approach is also reminiscent of Angeletos and Pavan (2007, 2009) and Angeletos and La'O (2020): they use team theory to solve the planning problem in a multiple-agent economy with dispersed information.

By viewing the decision maker as a collection of multiple selves, the paper also connects to the literature on multiple-selves (Piccione and Rubinstein, 1997; Benabou and Tirole, 2002, 2003, 2004; Gottlieb, 2014). In this literature, multiple selves have *conflicted interests*. The multiple selves of the narrow thinker, on the other hand, have *common interests*. Despite common interests, since different selves do not share their information, they have difficulty in coordinating their decisions in response to shocks to the fundamental.

Layout. Section 2 defines the notion of narrow thinking. Section 3 uses a simple consumer theory example to illustrate how narrow thinking implies narrow bracketing. Section 4 turns to the main application: how narrow thinking provides a smooth model of mental accounting. Section 5 studies additional applications and extensions. The Appendix, available online and in supplementary materials, contains proofs and additional results.

2 Narrow Thinking in a Multiple-Decision Problem

This section introduces a general multiple-decision problem and defines the notion of narrow thinking: different decisions are based on different, non-nested, information. I then recast this individual decision problem as multiple selves playing an incomplete-information, common interest game. This representation illustrates how each of the narrow thinker's decisions is made with imperfect knowledge of the other decisions, and how the narrow thinker has difficulty in coordinating her multiple decisions.

Utility. The decision maker's utility depends on N decisions $\vec{x} = (x_1, \cdots, x_N) \in \mathcal{X}_1 \times \cdots \times \mathcal{X}_N$ and the fundamental $\vec{\theta} = (\theta_1, \cdots, \theta_M) \in \Theta$:

$$u\left(\vec{x}, \vec{\theta}\right), \tag{1}$$

where $u : \mathcal{X}_1 \times \cdots \times \mathcal{X}_N \times \Theta \to \mathbb{R}$ is twice continuously differentiable and strictly concave over $\vec{x}$. For each i, a convex set $\mathcal{X}_i \subseteq \mathbb{R}$ denotes the set of possible decisions x_i. $\Theta \subseteq \mathbb{R}^M$ denotes the set of possible fundamentals $\vec{\theta}$.

Information. I let $(S, \mathcal{F}, P)$ denote the probability (state) space. The fundamental $\vec{\theta}$ should be viewed as an exogenously drawn random vector on S. To accommodate narrow thinking, I introduce *decision*-specific information. For each decision $i \in \{1, \cdots, N\}$, I use $s_i \in \Omega_i$ to denote the information, i.e., signal (potentially multi-dimensional), under which decision i is made, where $\Omega_i \subseteq \mathbb{R}^l$ denotes the set of possible signal realizations for decision i. One can interpret s_i as the *state of mind* when the decision maker decides x_i. Here, each s_i is an exogenously drawn random vector on S. Later, in Section 5, I study a problem in which the decision maker endogenously chooses the information upon which each decision is based.

Decision problem. The decision maker jointly chooses all her decision rules $\{x_i(\cdot) : \ \Omega_i \to \mathcal{X}_i\}_{i=1}^N$

to maximize her expected utility,

$$\max_{\{x_i(\cdot)\}_{i=1}^N} E\left[u\left(x_1\left(s_1\right), \cdots, x_N\left(s_N\right), \vec{\theta}\right)\right]. \tag{2}$$

The only restriction embedded in (2) is an information constraint: each decision i needs to be a function of its signal s_i. Compared to the standard Bayesian decision paradigm, the only difference is that the information constraint is *decision*-specific.

Mathematically, the problem in (2) is essentially a "team" problem in the sense of Marschak and Radner (1972). In Marschak and Radner (1972), the objective is the common payoff of the team, and the constraint is a team-member-specific information constraint. In the single-agent multiple-decision context studied here, one can think of the decision maker as a team of multiple selves (Piccione and Rubinstein, 1997). The common objective is the utility of the decision maker, and the constraint is a self-specific information constraint.

Since u is strictly concave over $\vec{x}$, the optimum of (2), if it exists, is unique.[3][4]

Narrow thinking. I now introduce the notion of narrow thinking used throughout the paper: different decisions are made based on different, non-nested, information.

Definition 1 *A decision maker is a narrow thinker if there are at least two decisions (i, j) such that they are made based on different, non-nested, information. This means that, in the sense of Blackwell, neither decision i's signal is more informative than decision j's signal nor decision j's signal is more informative than decision i's signal.*[5]

As an example of a narrow thinker, consider a simple consumer theory example. When the decision maker purchases food, she perfectly knows the food price. However, she does not have the gasoline price at the front of her mind, i.e. she only receives a noisy signal about the gasoline price. When she purchases gasoline, she perfectly knows the gasoline price, but only receives a noisy signal about the food price. This decision maker is a narrow thinker, since her two consumption decisions are based on different, non-nested, information. In Section 3, I further study this example and discuss the psychological justifications for narrow thinking, e.g., bounded recall and selective retrieval from memory.

Broad thinking. I contrast the notion of narrow thinking with broad thinking. Broad thinking lets the multiple-decisions be made based on the same information.[6]

[3] Uniqueness is in the sense that, in any two optima, decision rules are the same almost surely.

[4] For generality, I do not restrict the potential set for each x_i, $\mathcal{X}_i$, to be compact. As a result, the optimum of (2) may not exist. However, for all applications studied below, the existence of the optimum is guaranteed.

[5] Mathematically, let $\mathcal{F}_i$ denote the $\sigma-$algebra (on the probability space S) generated by decision i's signal s_i: $\mathcal{F}_i \equiv \left\{s_i^{-1}\left(B\right) : B \in \mathbb{B}_l\right\}$, where $\mathbb{B}_l$ is the collection of Borel sets on $\mathbb{R}^l$ and l is the dimensionality of s_i. A decision maker is a narrow thinker if there exists a pair of $(i, j) \in \{1, \cdots, N\}$ such that $\mathcal{F}_i \nsubseteq \mathcal{F}_j$ and $\mathcal{F}_j \nsubseteq \mathcal{F}_i$.

[6] One may wonder what happens if different decisions are made based on different, but *nested*, information.

Definition 2 *A decision maker is a broad thinker if all decisions are made based on the same information.*[7]

In the consumer theory example mentioned above, the notion of broad thinking nests both classical consumer theory and a few standard bounded rationality approaches (e.g., rational inattention and sparsity). When all decisions are based on the same, perfect, knowledge of the fundamental $\vec{\theta}$, i.e. the price vector, the decision problem in (2) coincides with the standard consumer problem (Mas-Colell, Whinston and Green, 1995). When all decisions are based on the *same*, *imperfect*, knowledge of the price vector, the decision problem in (2) coincides with rational inattention (Koszegi and Matejka, 2020) and sparsity (Gabaix, 2014).

Narrow thinking captures a decision maker's difficulty in coordinating her own decisions. The problem in (2) is a single-agent planning problem: the decision maker makes all decisions jointly, subject to a decision-specific information constraint. To help better understand how narrow thinking captures a decision maker's difficulty in coordinating her decisions, it is useful to provide an equivalent, game-theoretic, representation of (2).

First notice, since the utility $u(\cdot)$ is strictly concave over $\vec{x}$, the following decision-by-decision optimality condition is a necessary and sufficient condition for the optimum in (2).

Lemma 1 $\{x_1^*(\cdot), \cdots, x_N^*(\cdot)\}$ *solves (2) if and only if, almost surely,*

$$x_i^*(s_i) = arg\max_{x_i} E\left[u\left(x_1^*(s_1), \cdots, x_i, \cdots, x_N^*(s_N), \vec{\theta}\right)|s_i\right] \quad \forall i, s_i \in \Omega_i. \tag{3}$$

Condition (3) means that, for each i, the optimal decision $x_i^*(s_i)$ maximizes the decision maker's expected utility, given the signal realization s_i and the optimal decision rules for other decisions.

Lemma 1 points to the equivalence between the decision problem under narrow thinking and an incomplete information, common interest, game G among multiple selves. In this game, each player i corresponds to self i, who is in charge of decision i given her signal s_i. All players share the same payoff function $u\left(\vec{x}, \vec{\theta}\right)$. Condition (3) characterizes the optimal strategy for each self i.

Proposition 1 *The Bayesian Nash Equilibrium in the incomplete information, common interest game G among multiple selves coincides with the optimum in (2).*

The incomplete information game representation in Proposition 1 helps illustrate why a narrow thinker has difficulty in coordinating her multiple decisions. Under narrow thinking, different

Formally, following Footnote 5, this means $\mathcal{F}_i \subseteq \mathcal{F}_j$ for all $i < j$. This case corresponds to the standard sequential decision problem with perfect recall: the information of the earlier decision i is perfectly nested by the information of the later decision j. Section 3.2 further discusses how to interpret narrow thinking in sequential settings.

[7]Formally, following Footnote 5, Definition 2 means that, for all $i \neq j$, $\mathcal{F}_i = \mathcal{F}_j$.

decisions are made based on different, non-nested, information. In the Bayesian Nash Equilibrium of the equivalent game, each self's imperfect knowledge about other selves' information then translates into her imperfect knowledge about other selves' decisions. This means that, when the decision maker makes a particular decision, she has an imperfect perception of other decisions. In this sense, the narrow thinker faces friction in coordinating her multiple decisions. As the later analysis shows, this friction effectively attenuates the interaction across decisions and provides a smooth model of narrow bracketing.

Under broad thinking, however, different decisions are made based on the same information. The game among multiple selves becomes a complete information game. Each self's knowledge about other selves' information translates into her perfect knowledge about other selves' decisions. The decision maker is then able to fully consider the impact of other decisions when making a decision. In this sense, she can perfectly coordinate her multiple decisions and broadly bracket. Under broad thinking, it is as if all decisions are made together.

Transforming a constrained problem into an unconstrained problem. The problem considered above is an unconstrained optimization problem. In applications, one sometimes faces a constrained problem in which the fundamental and decisions need to satisfy

$$B\left(\vec{x}, \vec{\theta}\right) \leq 0, \tag{4}$$

where B is twice continuously differentiable and convex over $\vec{x}$.

Here I provide a simple and standard approach to transform a constrained problem under narrow thinking into the unconstrained problem in (2): I let the last decision x_{N+1} adjust automatically given the constraint and other boundedly rational decisions. Under mild conditions,[8] the constraint in (4) always binds in the optimum. One can then use this constraint to substitute x_{N+1} in the utility, and the problem becomes an unconstrained problem in (2) for the first N decisions.

For example, in the consumer theory setting (Section 3 and 4), one can interpret the last decision as saving or borrowing (allowed to be negative) and let it adjust given the budget constraint and the consumption decisions under narrow thinking. In fact, this is similar to Sims (2003), who lets saving adjust automatically based on the budget constraint and the boundedly rational consumption decision.

[8]For example, the utility $u\left(\vec{x}, \vec{\theta}\right)$ in (1) and the constraint $B\left(\vec{x}, \vec{\theta}\right)$ in (4) increase in each decision x_i.

3 A Simple Example: Narrow Thinking as a Model of Narrow Bracketing

In this section, I use a simple consumer theory example to illustrate several key insights: how narrow thinking effectively attenuates the interaction across decisions and provides a smooth model of narrow bracketing.

3.1 Narrow Thinking in a Simple Consumer Theory Example

Setup. The decision maker's utility depends on her consumption of two goods $x_1 \in \mathbb{R}^+$ and $x_2 \in \mathbb{R}^+$ ("food" and "gasoline") and is quasi-linear in the last good $y \in \mathbb{R}$ ("saving" or "borrowing"):

$$v(x_1, x_2) + y,$$

where v is strictly concave, twice continuously differentiable, and increasing in (x_1, x_2). As discussed above, one can substitute y based on the budget constraint $p_1 x_1 + p_2 x_2 + y \leq w$, and express the decision maker's utility as

$$u(x_1, x_2, p_1, p_2) = v(x_1, x_2) + w - p_1 x_1 - p_2 x_2, \tag{5}$$

where p_i is good i's price and w is the decision maker's wealth (treated as a constant, since I am interested in the response to price shocks here).

Here, the interaction between the two consumption decisions comes from the complementarity/substitutability embedded in the utility function (second-order cross-derivatives of v). There are no income effects. In the next section about mental accounting, I study the non-quasi-linear case where the interaction across decisions comes from the budget constraint.

Narrow thinking. In the consumer theory example here, it is natural to consider the following narrow thinker: she perfectly knows the price of the good she buys, but only receives a noisy signal about the other price.

Mathematically, I let prices and signals be log-normally distributed. This facilitates the analytical characterization of the narrow thinker's behavior and makes sure that prices are always positive. Each self $i \in \{1, 2\}$ of the narrow thinker, who is in charge of purchasing good i, perfectly sees $p_i \sim \log \mathcal{N}\left(\log \bar{p}_i, \sigma_{p_i}^2\right)$, but receives a noisy signal about each of the other p_{-i}: $s_{i,-i} = p_{-i}\epsilon_{i,-i}$, with $\epsilon_{i,-i} \sim \log \mathcal{N}\left(0, \sigma_{i,-i}^2\right)$, $\sigma_{i,-i}^2 > 0$, and all ϵ and p are independent of each other. That is, for self $i \in \{1, 2\}$, her information is given by $s_i = \{p_i, s_{i,-i}\}$.

Psychological foundations. Why are different decisions made based on different, non-nested, information? Multiple cognitive frictions can lead to narrow thinking. First, narrow thinking can arise because of bounded recall (Ebbinghaus, 1885; Kahana, 2012; Bordalo, Gennaioli and Shleifer, 2020). For example, the recency effect in psychology documents that a person often only has perfect recall of the last few items she has encountered (Kahana, 2012). In the consumer theory context here, such bounded recall means that when the decision maker purchases food (gasoline), she may not perfectly remember the gasoline (food) price and consumption.

Second, narrow thinking can arise because of selective retrieval from memory (Anderson, 2009). That is, when the decision maker makes a particular decision, she only evokes a very limited amount of information stored in her memory (Tversky and Kahneman, 1973; Gennaioli and Shleifer, 2010). In the consumer theory context here, a relevant observation is the "What You See Is All There Is" principle emphasized by Kahneman (2011) and Enke (2020): when the decision maker purchases food (gasoline), she only sees the food (gasoline) price and does not have the gasoline (food) price at the front of her mind.

Third, narrow thinking can arise because of imprecise cognition and perception (Enke and Graeber, 2019; Khaw, Li and Woodford, 2020; Woodford, 2020), i.e., the psychophysics observation that a decision maker may only have a noisy representation of (part of) the economic environment she faces. In the consumer theory context here, when the decision maker purchases food (gasoline), her mental representation of the gasoline (food) price may be noisy.

Finally, in Section 5, I study a problem where the decision maker optimally chooses what information each decision is based upon, subject to a cognitive cost. In the consumer theory context here, each self will endogenously choose to know more about the price of the good she buys.

In the analysis below, I show that narrow thinking effectively attenuates the interaction across decisions and provides a smooth model of narrow bracketing (here) and mental accounting (Section 4). The main results are derived from the definition of narrow thinking, i.e., different decisions based on different, non-nested, information. They are independent from the detailed psychological foundations discussed here. But the psychological foundations can further inform about when the degree of narrow bracketing and mental accounting behavior is higher.

Log-linearization. As I am interested in demand elasticities, I work with log-linearized optimal decision rules throughout. Specifically, I log-linearize around the point where each price is fixed at $\bar{p}_i$ and each decision is made with perfect knowledge of all prices: $\{\bar{x}_i\}_{i=1}^2 = \arg\max_{\{x_i\}_{i=1}^2} u(x_1, x_2, \bar{p}_1, \bar{p}_2)$. I use a hat over a variable to denote its log-deviation from this point, e.g., $\hat{x}_i = \log \frac{x_i}{\bar{x}_i}$. As Appendix C illustrates, one can also establish parallel results with linearized optimal decision rules. In that case, the main results are stated in terms of gradients instead of elasticities.

Optimal consumption decisions. The narrow thinker's optimal consumption decision for each good i is given by the decision-by-decision optimality in (3). Given the environment in (5), I take the first order condition of (3) and log-linearize it. I arrive at the following optimal consumption decision rule for the narrow thinker: for $i \in \{1,2\}$,

$$\hat{x}_i^*(s_i) = \underbrace{-\psi_i \hat{p}_i}_{\text{Direct effect. Maintained.}} + \underbrace{\gamma_{i,-i} E_i\left[\hat{x}_{-i}^*(s_{-i})\right]}_{\text{Indirect effect. Dampened.}}, \tag{6}$$

where $E_i[\cdot] = E[\cdot|s_i]$, $\psi_i = -\frac{1}{v_{x_i,x_i}}\frac{\bar{p}_i}{\bar{x}_i} > 0$, and $\gamma_{i,-i} = -\frac{v_{x_i,x_{-i}}}{v_{x_i,x_i}}\frac{\bar{x}_{-i}}{\bar{x}_i}$.[9]

The first term in (6) captures the direct effect of price changes on consumption x_i, that is, the effect of $\vec{p} = (p_1, p_2)$ holding other decisions fixed. ψ_i parameterizes the size of such an effect. As self i perfectly knows the price of the good she purchases, the direct effect is the same as in standard consumer theory.

The second term in (6) captures the indirect effect on x_i, that is, the impact of other consumption decisions on x_i. A positive (negative) $\gamma_{i,-i}$ means that two goods are complements (substitutes), and that the optimal consumption of good i increases (decreases) with self i's belief about each of the other consumption x_{-i}. Under narrow thinking, since the coordinated response of x_{-i} is limited, this indirect effect will be dampened.

Narrow thinker's demand. The main question of interest is the narrow thinker's demand elasticity, i.e., how her consumption responds to small price changes. I define the narrow thinker's (log) demand as a function of (log) prices: for $i \in \{1,2\}$,

$$\hat{x}_i^{\text{Narrow}}(\hat{p}_1, \hat{p}_2) \equiv E\left[\hat{x}_i^*(s_i)\,|\hat{p}_1, \hat{p}_2\right], \tag{7}$$

averaging over the realization of noises in signals. It can be directly compared to $\hat{x}_i^{\text{Standard}}(\hat{p}_1, \hat{p}_2)$, the (log) demand function in standard consumer theory, in which the decision maker makes each consumption decision with perfect knowledge of all prices.

The limit case: narrow thinking implies complete narrow bracketing. First consider the limit case when each self's signal about the other price is infinitely noisy: $\sigma_{1,2}^2, \sigma_{2,1}^2 = +\infty$ (equivalently $\lambda_{1,2}, \lambda_{2,1} = 0$, where $\lambda_{i,-i} \equiv \frac{\sigma_{p_{-i}}^2}{\sigma_{p_{-i}}^2 + \sigma_{i,-i}^2} \in [0,1]$ captures the precision of self i's signal about p_{-i}). In this case, narrow thinking implies complete narrow bracketing: in response to price shocks, each self behaves as if she completely neglects the influence of the other decision.

Lemma 2 *When $\sigma_{1,2}^2, \sigma_{2,1}^2 = +\infty$, the narrow thinker's demand for good $i \in \{1,2\}$ is given by*

$$\hat{x}_i^{\text{Narrow}}(\hat{p}_1, \hat{p}_2) = -\psi_i \hat{p}_i \equiv \hat{x}_i^{\text{Neglect}}(\hat{p}_1, \hat{p}_2). \tag{8}$$

[9] Here, $v_{x_i,x_{-i}} = \frac{\partial^2 v(\bar{x}_1,\bar{x}_2)}{\partial x_1 \partial x_2}$ and $v_{x_i,x_i} = \frac{\partial^2 v(\bar{x}_1,\bar{x}_2)}{(\partial x_i)^2}$.

To illustrate the intuition behind Lemma 2, consider the response of x_i to p_i. In this limit case, the other self $-i$ will not perceive or respond to changes in p_i. As a result, for consumption x_i, the indirect effect from the coordinated response of consumption x_{-i} is completely muted. The narrow thinker's demand for x_i is then the same as the demand of a decision maker who completely neglects the other decision (x_i^{Neglect}).

Consider responses to food price changes as an example. For a complete narrow thinker, her gasoline consumption will not respond to food price changes. As a result, she decides her food consumption as if she neglects the interaction with gasoline consumption. In this sense, narrow thinking implies complete narrow bracketing.

The general case: a smooth model of narrow bracketing. I now turn to the general case where $\sigma_{1,2}^2, \sigma_{2,1}^2 < +\infty$. In this case, the indirect effect in (6) is dampened but not completely muted. Narrow thinking then provides a smooth model of narrow bracketing.

Proposition 2 *The narrow thinker's own-price demand elasticity for each good $i \in \{1,2\}$ is given by:*

$$\frac{\partial \hat{x}_i^{\text{Narrow}}}{\partial \hat{p}_i} = \omega_i \frac{\partial \hat{x}_i^{\text{Neglect}}}{\partial \hat{p}_i} + (1-\omega_i)\frac{\partial \hat{x}_i^{\text{Standard}}}{\partial \hat{p}_i}, \tag{9}$$

where $\omega_i = \frac{1-\lambda_{-i,i}}{1-\lambda_{-i,i}\gamma_{i,-i}\gamma_{-i,i}} \in [0,1]$ captures the weight on $x_i^{Neglect}$. Moreover,

(i) ω_i increases when the interaction across consumption decisions $\gamma_{i,-i}\gamma_{-i,i} = \frac{v_{x_1,x_2}^2}{v_{x_1,x_1}v_{x_2,x_2}} \geq 0$ is larger.

(ii) ω_i increases when the other self $-i$'s signal about p_i is less precise (a lower $\lambda_{-i,i}$).

Proposition 2 shows that, in response to shocks to each p_i, the narrow thinker's demand (x_i^{Narrow}) can be written as a weighted average between the demand in standard consumer theory (x_i^{Standard}) and the demand when the decision maker completely neglects the other decision (x_i^{Neglect}). In this sense, narrow thinking bridges the gap between these two polar cases and provides a smooth model of narrow bracketing.

The intuition behind Proposition 2 is similar to Lemma 2: since the other self $-i$ will not perfectly perceive and respond to shocks to p_i, the response of x_i to p_i is less influenced by the indirect effect from the coordinated response of x_{-i}; self i then behaves as if she cares less about the other self. Consider responses to food price changes as an example. For a narrow thinker, since her gasoline consumption is not as responsive to food price changes, her food consumption will be closer to the case where she neglects the interaction with gasoline consumption.

By providing a smooth model of narrow bracketing, Proposition 2 illustrates the difference from the existing models of narrow bracketing (Barberis, Huang and Thaler, 2006; Rabin and Weizsacker, 2009), which directly let the decision maker make each decision in isolation (as in

x_i^{Neglect}).[10,11]

The narrow thinking approach further generates unique predictions about what drives the degree of narrow bracketing behavior, ω_i. Part (i) of Proposition 2 shows that a larger interaction across decisions leads to a larger degree of narrow bracketing ω_i. This is because a larger interaction means that the effective attenuation of interaction under narrow thinking is more important.

Part (ii) of Proposition 2 shows that if the other self's signal about p_i is more noisy (a lower $\lambda_{-i,i}$), ω_i becomes larger and the decision maker narrowly brackets more. This prediction is independent from the exact psychological foundations discussed above. As long as different consumption decisions are made based on more distant mental states (potentially driven by more bounded recall, more selective retrieval from memory, or less precise cognition), the decision maker will narrowly bracket more.

These foundations, however, help if one wants to predict when $\lambda_{-i,i}$ is lower. For example, the noise in the other self's signal about p_i may come from selective retrieval from memory. Since memory is associative, retrieval from memory is often triggered by similarity (Kahana, 2012; Bordalo, Gennaioli and Shleifer, 2020). This means that if the two goods do not share common attributes, it will be harder for the other self to retrieve p_i when deciding on x_{-i}. In this case, $\lambda_{-i,i}$ will be lower and there will be more narrow bracketing (a higher ω_i).

As another example, in Section 5 and Appendix F, I let the decision maker endogenously choose what information each decision is based upon. Based on this foundation, if the price of good i is less volatile (a lower $\sigma_{p_i}^2$), the other self will choose to know less about p_i (a lower $\lambda_{-i,i}$), since the utility loss of narrow thinking is smaller.[12] The decision maker will then narrowly bracket more in response to p_i (a higher ω_i). Moreover, a more cognitively constrained decision maker, who can be interpreted as having a larger cognitive cost ϕ in the endogenous narrow thinking problem, will also have a lower $\lambda_{-i,i}$ and display more narrow bracketing behavior. This prediction is also consistent with the observation in Read, Loewenstein and Rabin (1999): cognitive limitations are an important determinant of bracketing.

Predictions about demand elasticities. Based on the lessons above, I now directly compare

[10] Barberis, Huang and Thaler (2006) and Rabin and Weizsacker (2009) focus on narrow bracketing behavior in a different context, i.e., myopic loss aversion. See Section 5 for a detailed analysis of narrow thinking in that context. Here, I use the consumer theory example because it illustrates how narrow thinking leads to narrow bracketing in the simplest manner. In both cases, each self of the narrow thinker behaves as if she does not care enough about the other decision.

[11] The narrow thinking approach provides a potential foundation for the reduced-form utility used in Barberis, Jin and Wang (2019). There, utility is given by a weighted average between the standard utility and the narrowly bracketed utility, which seems to have a better empirical fit than the two polar cases.

[12] The prediction that a lower variance of p_i leads to less knowledge about it is also consistent with Kőszegi and Szeidl (2013): a narrower range diminishes the focus a person places on a dimension. On the other hand, Bushong, Rabin and Schwartzstein (2020) study a potential countervailing effect named relative thinking: a narrower range can draw the decision maker's attention to a given change of p_i. It is an open question which effect dominates.

demand elasticities of the narrow thinker with those from standard consumer theory.

Corollary 1 *(i) The narrow thinker's cross-price demand elasticities are attenuated: for* $i \in \{1, 2\}$ *,*

$$\left| \frac{\partial \hat{x}_{-i}^{\text{Narrow}}}{\partial \hat{p}_i} \right| \leq \left| \frac{\partial \hat{x}_{-i}^{\text{Standard}}}{\partial \hat{p}_i} \right|. \tag{10}$$

(ii) The narrow thinker's own-price demand elasticities are attenuated: for $i \in \{1, 2\}$ *,*

$$\frac{\partial \hat{x}_{i}^{\text{Standard}}}{\partial \hat{p}_i} \leq \frac{\partial \hat{x}_{i}^{\text{Narrow}}}{\partial \hat{p}_i} < 0. \tag{11}$$

Part (i) of Corollary 1 shows that narrow thinking attenuates cross-price demand elasticities. This mostly comes from "what comes to mind," that is, the fact that each self only receives a noisy signal about the other price.[13]

More interestingly, Part (ii) of Corollary 1 shows that narrow thinking also attenuates own-price demand elasticities. First consider the complementarity case with $\gamma > 0$. Use an increase in food price p_i as an example. From (6), this increase has a negative direct effect on food consumption x_i. In standard consumer theory, the increase also has a negative indirect effect on food consumption x_i: because of the complementarity, gasoline consumption x_{-i} will also decrease, which will further decrease food consumption. Under narrow thinking, the indirect effect from the coordinated response of gasoline consumption x_{-i} is dampened. Food consumption x_i then decreases less in response to the increase in p_i.

Now consider the substitutability case with $\gamma < 0$. An increase in food price p_i has a negative direct effect on food consumption x_i. Moreover, the increase in food price p_i still has a negative indirect effect on food consumption x_i: because of substitutability, gasoline consumption x_{-i} will now increase, which will again further decrease food consumption. Under narrow thinking, the indirect effect from the coordinated response of gasoline consumption x_{-i} is dampened, and x_i decreases less in response to an increase in p_i.

In sum, since the indirect effect of p_i on x_i through x_{-i} comes from a second degree interaction, it is always in the same direction as the direct effect. As a result, it is always true that $\frac{\partial \hat{x}_{i}^{\text{Standard}}}{\partial \hat{p}_i} \leq \frac{\partial \hat{x}_{i}^{\text{Neglect}}}{\partial \hat{p}_i}$. Moreover, the comparative statics in Proposition 2 regarding the degree of narrow bracketing easily translate into predictions regarding own-price demand elasticities: a larger degree of narrow bracketing ω_i leads to more attenuation of own-price demand elasticities.

[13] In fact, for $i \in \{1, 2\}$, $\frac{\partial \hat{x}_{-i}^{\text{Narrow}}}{\partial \hat{p}_i} = \lambda_{-i,i} \left[\omega_i \frac{\partial \hat{x}_{-i}^{\text{Neglect}}}{\partial \hat{p}_i} + (1 - \omega_i) \frac{\partial \hat{x}_{-i}^{\text{Standard}}}{\partial \hat{p}_i} \right]$. That is, beyond "what comes to mind" (captured by $\lambda_{-i,i}$), "narrow bracketing" in Proposition 2 also contributes to the attenuation of cross-demand elasticities.

3.2 Discussion and Additional Predictions

Comparison with rational inattention. Here, since each self i knows the price of the good she buys, the direct effect of p_i on x_i is the same as the direct effect in standard consumer theory. The friction comes solely from the dampening of indirect effects. On the other hand, when applying rational inattention and sparsity to the consumer theory problem here (e.g., Gabaix, 2014 and Koszegi and Matejka, 2020), different decisions are based on the same imperfect knowledge about prices. The key friction is the frictional direct effects. The decision maker nevertheless perfectly knows her other decisions when making a particular decision. In fact, a form of certainty equivalence emerges for the rationally inattentive decision maker: one can use the standard frictionless decision function, $x_i^{\text{Standard}}(\cdot)$, to characterize her decision. Her consumption for good i is given by $x_i^{\text{Standard}}(E[\vec{p} \mid s])$, where s is her imperfect signal about prices (shared by all selves). Narrow thinking, on the other hand, breaks this certainty equivalence: $x_i^*(s_i) \neq x_i^{\text{Standard}}(E[\vec{p} \mid s_i])$.

Slutsky asymmetry. Under narrow thinking, as long as $\lambda_{1,2} \neq \lambda_{2,1}$, that is, when the signal-to-noise ratio of self 1's signal about p_2 differs from the signal-to-noise ratio of self 2's signal about p_1, the Slutsky matrix is asymmetric.[14] It is worth noting that rational inattention and sparsity can also lead to Slutsky asymmetry (Gabaix, 2014; Abaluck and Adams, 2021), but for a different reason. In those papers, different decisions are based on the same imperfect knowledge about prices. Slutsky asymmetry arises if the decision maker's signals about p_1 and p_2 have different precision.

Frictional response to shocks and unbiasedness on average. The above frictional behavior under narrow thinking is about responses to price shocks. Since the narrow thinker's prior about prices coincides with their statistical mean, the narrow thinker's behavior is unbiased on average.[15]

Proposition 3 *On average, each narrow thinker's decision coincides with the frictionless one:*

$$E\left[\hat{x}_i^{\text{Narrow}}\right] = E\left[\hat{x}_i^{\text{Standard}}\right] \quad \forall i, \tag{12}$$

where $E[\cdot]$ averages over the realization of all fundamentals and signals.

Based on this prediction, the narrow thinker's demand elasticity estimated based on temporary price shocks can differ from the demand elasticity estimated based on persistent price differences.

[14]Note that the Slutsky matrix is about demand gradients instead of demand elasticities. To derive demand gradients from demand elasticities (at the point of log-linearization), we have, for all i, k, $\frac{\partial x_i^{\text{Narrow}}}{\partial p_k} = \frac{\partial \hat{x}_i^{\text{Narrow}}}{\partial \hat{p}_k} \frac{\bar{x}_i}{\bar{p}_k}$.

[15]Proposition 3 is only true within the context of the (log-)linearized decision rules in (6). However, the observation that the narrow thinker's demand elasticity estimated based on temporary price shocks can differ from the demand elasticity estimated based on persistent price differences holds more generally.

This result is different from the standard consumer theory. Appendix B provides further discussion along this line.

Testable predictions of narrow thinking. Besides the comparative statics in Proposition 2, let me provide two other unique testable predictions of narrow thinking.

First, from Proposition 3, the narrow thinker's frictional behavior is about responses to temporary shocks. This means that the narrow thinker narrowly brackets in response to temporary price shocks, but broadly brackets with respect to persistent variations in her economic environment. In other words, the degree of narrow bracketing in (9) will be larger and the own-price demand elasticities in Corollary 1 will be smaller in response to temporary price shocks.

Second, recall that narrow thinking arises because different decisions are made based on different information, i.e., different states of mind. On the other hand, if the two decisions are made together based on the same state of mind, the decision maker will be a broad thinker. In the consumer theory example here, this means that the decision maker will narrowly bracket more when she makes the two consumption decisions separately. In other words, the degree of narrow bracketing in (9) will be larger, and the own-price demand elasticities in Corollary 1 will be smaller if the two decisions are made separately. This prediction is consistent with the observation of "cognitive inertia" in Read, Loewenstein and Rabin (1999): if multiple decisions come to the decision maker one at a time, she will bracket them narrowly; if multiple decisions come to the decision maker collectively, she will bracket them more broadly. Evidence on such cognitive inertia can be found in Redelmeier and Tversky (1992), Kahneman and Knetsch (1992), and Schkade and Payne (1994).[16]

The role of sophistication. In the language of O'Donoghue and Rabin (2001), each self i here is "sophisticated" since she understands that the other self does not perfectly perceive or respond to shocks to p_i. Such sophistication is naturally embedded in the standard solution concept of the Bayesian Nash Equilibrium in the incomplete information game among multiple selves: each self understands that the other self faces incomplete information.[17] I henceforth maintain it for self-discipline. It is also easy to incorporate partial sophistication in the sense of O'Donoghue and Rabin (2001) in my setting: each self i thinks other selves receive a noisy signal about p_i; but her beliefs about the variances in these noises are smaller than the actual variances. The key

[16]For example, Redelmeier and Tversky (1992) find that the decision maker narrowly brackets more when making two decisions sequentially in a separate fashion. It is worth noting that, even when two decisions are made on the same page/screen, the decision maker sometimes still narrowly brackets (Tversky, Kahneman et al., 1986). There are two potential explanations. First, because those decisions are cognitively costly, they are still made based on different states of minds, even though on the same page/screen. Second, there are other reasons of narrow bracketing beyond narrow thinking.

[17]The game-theoretic foundation in Proposition 1 does not mean that the narrow thinker needs to incur sophisticated game theoretic thinking. She can learn over time based on her past behavior in similar situations that her consumption of other goods may not be very sensitive to shocks to p_i. In fact, such learning foundations have been developed for the Bayesian Nash Equilibrium (Fudenberg and Levine, 2009).

qualitative results still hold with partial sophistication.

It is worth noting that "sophistication" does not necessarily lead to complicated behavior. As Lemma 2 shows, narrow thinking can actually lead to simpler behavior than the frictionless benchmark: when the friction is large enough, the decision maker effectively ignores the impact of the other decision.

Effective attenuation of interaction in the general case. The insight that narrow thinking effectively attenuates the interaction across decisions can be extended to the general case introduced in Section 2. In Appendix D, I use an "interaction matrix" to capture how different selves' decisions depend on each other. I then show how narrow thinking attenuates (the absolute value of) each element of the interaction matrix, effectively attenuating the interaction across decisions.

Interpretation in a sequential setting. Above, I analyze the narrow thinker's demand based on a *static*, incomplete-information game among multiple selves. This analysis is aligned with standard consumer theory, which treats the demand for multiple goods as a static problem. One may naturally wonder how to interpret my analysis about the narrow thinker's behavior in an explicit sequential setting.

In fact, in a sequential setting, the narrow thinker studied above can be interpreted as a particular form of bounded recall (or selective retrieval from memory). Consider the simple two goods consumer theory example studied in this Section and let consumption x_1 be decided before x_2. For the above narrow thinker, when her self 1 decides on x_1, she perfectly knows the price p_1, but only receives a noisy signal about the price p_2.[18] When her self 2 decides on x_2, she perfectly knows the price p_2, but cannot perfectly recall her past decision x_1. Self 2's information structure introduced above essentially imposes a particular form of bounded recall (or selective retrieval from memory): she recalls her past decision x_1 only through a noisy signal about p_1 ($s_{2,1}$). In Appendix B, I show that, in terms of demand elasticities, this narrow thinker is observationally equivalent to a decision maker whose bounded recall is captured by a noisy signal about the past endogenous decision. I focus on the narrow thinker above as the analysis is much more tractable when there are $N \geq 3$ decisions.

In sum, one can view my approach based on the information structure used throughout the paper as a reduced form method to study the impact of bounded recall on otherwise standard multiple decision problems.

[18]For self 1 who decides first, the noise in her signal about p_2 allows for two interpretations. The noise can come from uncertainty. Alternatively, even if the uncertainty about p_2 is resolved before she decides on x_1, her noisy signal about p_2 can come from bounded recall, selective retrieval from memory, or imprecise cognition. Both interpretations lead to the same analysis.

4 A Smooth Model of Mental Accounting

I now show how narrow thinking provides a smooth model of mental accounting. For this purpose, I turn to the case where interaction across different decisions comes from the budget constraint. A typical explanation of mental accounting is based on explicit mental budgets (Heath and Soll, 1996), i.e., the decision maker allocates a fixed budget to each good or spending category. In my smooth model, a narrow thinker does not have an explicit mental budget. The difficulty in coordinating her decisions nevertheless moves her demand elasticity closer to the explicit mental budgeting model, where each decision can be made in isolation.

My approach to mental accounting also illustrates how narrow bracketing and mental accounting can be explained by the same underlying friction, i.e., narrow thinking. In the literature, those two phenomena are sometimes loosely connected (Read, Loewenstein and Rabin, 1999; Thaler, 1999), but require different models.

4.1 The Main Results

Environment. Since the discussion about mental accounting behavior is inherently connected to the budget constraint (Thaler, 1985, 1999), I consider the non-quasi-linear case where the interaction across different consumption decisions comes from the budget constraint. To isolate the channel of interest, I let the consumer have separable utilities. As a result, the channel studied in the previous section driven by the second cross-derivates of the utility function is muted here. Specifically, the consumer's utility is given by

$$\sum_{i=1}^{N} v_i\left(x_i\right) + h\left(y\right), \tag{13}$$

where $v_i\left(x_i\right) = \frac{x_i^{1-\kappa_i}}{1-\kappa_i}$ captures the consumer's utility from consuming good i and $\kappa_i > 0$ parameterizes the rate at which the marginal utility of consuming good i moves with x_i. A higher κ_i means the demand for good i is less elastic. In fact, $-1/\kappa_i$ can be viewed as the "Frisch" elasticity of demand for good i, i.e., the elasticity holding the marginal utility of money fixed.

Moreover, $h\left(y\right)$, a strictly concave function on $\mathbb{R}$, captures the consumer's utility from her last decision, which can be interpreted as utility from saving (borrowing) or the value of money. The residual decision y is allowed to be negative and this guarantees that the budget constraint, $\sum_{i=1}^{N} p_i x_i + y \leq w$, will always be satisfied. As discussed above, one can substitute y based on the budget and transform the problem into an unconstrained problem, with $u\left(x_1, \cdots, x_N, \vec{p}\right) = \sum_{i=1}^{N} v_i\left(x_i\right) + h\left(w - \sum_{i=1}^{N} p_i x_i\right)$.

Similar to Section 3, I consider the following narrow thinker: each self $i \in \{1, \cdots, N\}$ of the narrow thinker, who is in charge of purchasing good i, perfectly sees $p_i \sim \log\mathcal{N}\left(\log\bar{p}_i, \sigma^2_{p_i}\right)$, but receives a noisy signal about each of the other p_k: $s_{i,k} = p_k\epsilon_{i,k}$, with $\epsilon_{i,k} \sim \log\mathcal{N}\left(0, \sigma^2_{i,k}\right)$ and $\sigma^2_{i,k} > 0$. All ϵ and p are independent of each other. That is, for self $i \in \{1, \cdots, N\}$, her information is given by $s_i = \{p_i, s_{i,k}\}_{k\neq i,\ k\in\{1,\cdots,N\}}$.

Optimal decisions. Similar to Section 3, the main question of interest is the narrow thinker's demand elasticity, i.e., how her consumption responds to small price changes. I work with log-linearization and use a hat over a variable to denote its log-deviation from the point where each price is fixed at $\bar{p}_i$ and each decision is made with perfect knowledge of all prices: $\{\bar{x}_i\}_{i=1}^N = \arg\max_{\{x_i\}_{i=1}^N} u\left(x_1, \cdots, x_N, \bar{p}_1, \cdots, \bar{p}_N\right)$.[19]

The optimal consumption for each self $i \in \{1, \cdots, N\}$ is given by:

$$\underbrace{-\kappa_i\hat{x}_i^*\left(s_i\right)}_{\text{marginal utility of consuming good i}} = \hat{p}_i + E_i\left[\underbrace{-\kappa_y\hat{y}^*}_{\text{marginal value of money}}\right], \tag{14}$$

where $-\kappa_i\hat{x}_i^*\left(s_i\right)$ captures the marginal utility of consuming good i, $-\kappa_y E_i\left[\hat{y}^*\right]$ captures self i's belief about the marginal value of money, and $\kappa_y = -\frac{h''(\bar{y})\bar{y}}{h'(\bar{y})}$ captures the rate at which the marginal value of money $h'\left(y\right)$ moves with respect to y. Condition (14) means that, from each self i's perspective, her expected marginal rate of substitution between consumption x_i and consumption y should equal p_i. It holds because the last decision y will adjust based on x_i, and the standard perturbation argument holds between the consumption of x_i and y.

The log-linearized budget constraint is given by

$$\sum_{i=1}^N \mu_i\left(\hat{x}_i^*\left(s_i\right) + \hat{p}_i\right) + \mu_y\hat{y}^* = 0, \tag{15}$$

where $\mu_i = \frac{\bar{p}_i\bar{x}_i}{w}$ is the spending share of good i and $\mu_y = \frac{\bar{y}}{w}$ is the saving share at the point of log-linearization.

Violation of the fungibility principle. From (14), one can see directly that the fungibility principle is violated under narrow thinking. By the fungibility principle (Thaler, 1985, 1999), I mean the prediction in standard consumer theory that the marginal value of spending an additional unit of money on each good is the same:

$$-\kappa_i\hat{x}_i^{\text{Standard}}\left(\hat{p}_1, \cdots, \hat{p}_N\right) - \hat{p}_i = -\kappa_j\hat{x}_j^{\text{Standard}}\left(\hat{p}_1, \cdots, \hat{p}_N\right) - \hat{p}_j \quad \forall i \neq j. \tag{16}$$

[19]Specifically, $\hat{x}_i = \log\frac{x_i}{\bar{x}_i}$ and $\hat{y} = \log\frac{y}{\bar{y}}$, where $\bar{y} = w - \sum_{i=1}^N \bar{p}_i\bar{x}_i$. Note that the log-linearization is always valid in the neighborhood of the point of log-linearization no matter whether $\bar{y}$ is positive or negative, as long as $\bar{y} \neq 0$. Moreover, in Appendix C, I show that the main results, i.e., Propositions 4 and 5, remain to hold exactly with linearization, which also covers the case of $\bar{y} = 0$.

For a narrow thinker, since different selves have different information, they hold different beliefs about the marginal value of money, $-\kappa_y E_i[\hat{y}^*]$. The marginal value of spending an additional unit of money on each good i, $-\kappa_i \hat{x}_i^*(s_i) - \hat{p}_i = -\kappa_y E_i[\hat{y}^*]$, then also differs.

Lemma 3 *Under narrow thinking, for a pair of decisions (i, j), the marginal value of spending an additional unit of money can differ:*

$$-\kappa_i \hat{x}_i^*(s_i) - \hat{p}_i \neq -\kappa_j \hat{x}_j^*(s_j) - \hat{p}_j. \tag{17}$$

A "smooth" model of mental accounting. I now show how narrow thinking provides a smooth model of mental accounting. A typical formalization of mental accounting is based on explicit mental budgets (Heath and Soll, 1996). That is, the decision maker allocates an explicit budget w_i for each good i,

$$p_i x_i^{\text{Explicit}} = w_i. \tag{18}$$

In this explicit budgeting model, each decision can be made in isolation and there is no need for different decisions to coordinate. I will show that, even though the narrow thinker does not have explicit budgets as in (18), her difficulty in coordinating her decisions moves her demand elasticity closer to the explicit mental budgeting model. This result is in line with the lesson in the previous section about how the narrow thinker's difficulty in coordinating her decisions leads to a smooth model of narrow bracketing.

Specifically, using the budget (15) to substitute $\hat{y}^*$ in (14), for $i \in \{1, \cdots, N\}$,

$$\hat{x}_i^*(s_i) = -\frac{1 + \mu_i \frac{\kappa_y}{\mu_y}}{\kappa_i + \mu_i \frac{\kappa_y}{\mu_y}} \hat{p}_i - \frac{\frac{\kappa_y}{\mu_y}}{\kappa_i + \mu_i \frac{\kappa_y}{\mu_y}} E_i \left[\sum_{j \neq i} \mu_j \left(\hat{x}_j^*(s_j) + \hat{p}_j \right) \right]. \tag{19}$$

We can see that the response of consumption x_i to p_i depends crucially on the indirect effect from the coordinated responses of other x_j. Under narrow thinking, other selves will not perfectly perceive or respond to shocks to p_i. The response of x_i to p_i is then less influenced by the indirect effects from the coordinated responses of other x_j. This moves the response of x_i to p_i closer to the case of explicit budgeting in (18), in which only x_i responds to p_i.

For example, consider a change in the food price. Under standard consumer theory, the coordinated responses of other consumption make sure that food consumption does not need to absorb all the impact of the price change on the budget. Under narrow thinking, however, other consumption will respond less. The response of the food consumption will be closer to the explicit budgeting model in (18).

To formalize this intuition, similar to condition (7), for each i, I define the narrow thinker's (log) demand function as $\hat{x}_i^{\text{Narrow}}(\hat{p}_1, \cdots, \hat{p}_N) \equiv E[\hat{x}_i^*(s_i)|\hat{p}_1, \cdots, \hat{p}_N]$, averaging over the realization of noises in signals. I can then establish:

Proposition 4 *The narrow thinker's own-price demand elasticity is given by: for $i \in \{1, \cdots, N\}$,*

$$\frac{\partial \hat{x}_i^{\text{Narrow}}}{\partial \hat{p}_i} = \omega_i \frac{\partial \hat{x}_i^{\text{Explicit}}}{\partial \hat{p}_i} + (1-\omega_i) \frac{\partial \hat{x}_i^{\text{Standard}}}{\partial \hat{p}_i}, \tag{20}$$

where

$$\omega_i = 1 - \frac{\left(\sum_{j\neq i} \frac{\mu_j}{\kappa_j} \frac{\lambda_{j,i}\frac{\mu_y}{\kappa_y}}{\frac{\mu_y}{\kappa_y}+(1-\lambda_{j,i})\frac{\mu_j}{\kappa_j}} + \frac{\mu_y}{\kappa_y}\right)\left(\sum_{j\neq i} \frac{\mu_j}{\kappa_j} + \frac{\mu_i}{\kappa_i} + \frac{\mu_y}{\kappa_y}\right)}{\left(\sum_{j\neq i} \frac{\mu_j}{\kappa_j} \frac{\lambda_{j,i}\frac{\mu_y}{\kappa_y}}{\frac{\mu_y}{\kappa_y}+(1-\lambda_{j,i})\frac{\mu_j}{\kappa_j}} + \frac{\mu_i}{\kappa_i} + \frac{\mu_y}{\kappa_y}\right)\left(\sum_{j\neq i} \frac{\mu_j}{\kappa_j} + \frac{\mu_y}{\kappa_y}\right)} \in [0,1] \tag{21}$$

captures the weight on x_i^{Explicit} and $\lambda_{j,i} \equiv \frac{\sigma_{p_i}^2}{\sigma_{p_i}^2+\sigma_{j,i}^2} \in [0,1]$ captures the precision of self j's signal about p_i.

Proposition 4 shows that, in response to shocks to p_i, the narrow thinker's demand x_i^{Narrow} is given by a weighted average between demand in standard consumer theory (x_i^{Standard}) and demand with explicit budgeting (x_i^{Explicit}). In this sense, narrow thinking bridges the gap between these two polar cases and provides a smooth model of mental accounting.

Empirically, there is also support for such a smooth model of mental accounting. For example, Hastings and Shapiro (2013) find that gasoline consumption responds excessively to gasoline price changes,[20] as Proposition 4 and Corollary 3 below predict. However, gasoline consumption does not decrease one-to-one with the gasoline price as the rigid mental budgeting model in (18) predicts.

What drives the degree of mental accounting behavior. In (21), ω_i, the weight on x_i^{Explicit}, captures the deviation from standard consumer theory. It can be interpreted as the degree of mental accounting behavior. The next Proposition establishes comparative statics results about what drives the weight.

Proposition 5 *For $i \in \{1, \cdots, N\}$, the degree of mental accounting behavior $\omega_i \in [0,1]$ has the following properties:*

(i) ω_i increases when μ_y/κ_y is smaller. That is, when the saving share μ_y is smaller or the curvature of $h(y)$, κ_y, is larger.

(ii) ω_i increases when μ_i/κ_i is larger. That is, when the expenditure share of good i, μ_i, is larger or the curvature of $v_i(x_i)$, κ_i, is smaller.

[20] Hastings and Shapiro (2013) find that, when gasoline prices rise, consumers decrease their total gasoline expenditure to an extent that cannot be explained by neoclassical effects. In Appendix C, I show how to re-interpret my analysis to accommodate their setting: one can interpret each x_i as the consumption of a composite gasoline good (summarizing all gasoline consumption), and p_i as the consumption of a composite gasoline good. Consistent with their finding, my model predicts that the total gasoline consumption decreases excessively when gasoline prices rise.

(iii) ω_i increases when each self j's signal about p_i is less precise (a lower $\lambda_{j,i}$), for all $j \neq i$.

(iv) $\omega_i \to 1$ when $\lambda_{j,i} \to 0$ for all $j \neq i$ and $\frac{\mu_y}{\kappa_y} \to 0$. In this limit, the narrow thinker's behavior converges to the explicit budgeting model in (18).

(v) $\omega_i \to 0$ when $\mu_i/\kappa_i \to 0$. In this limit, the narrow thinker's behavior converges to the standard consumer theory.

Part (i) of Proposition 5 shows that a smaller μ_y/κ_y increases the degree of mental accounting behavior ω_i. Intuitively, a smaller saving share μ_y or a larger curvature κ_y means that there is less room for y to absorb the error made by other selves of the narrow thinker. The friction then moves the response of x_i to p_i closer to the explicit mental budgeting model. For example, consider a food price increase. As mentioned above, under narrow thinking, other consumption will not help much in absorbing the impact of the price increase on the budget. If there is also not much room for saving/borrowing y to absorb the price increase, the "burden" will fall on food consumption and its behavior will be closer to the explicit budgeting model in (18). In practice, this result means that a decision maker whose saving share is low will display more mental-accounting type behavior.

Part (ii) of Proposition 5 shows that a larger μ_i/κ_i also increases the degree of mental accounting behavior ω_i. A larger expenditure share of good i (μ_i) or a smaller curvature of its utility function (κ_i) means shocks to p_i and the response of x_i are more important in determining the marginal value of money. Other selves' imperfect perception of these changes under narrow thinking then becomes more problematic. This again moves the response of x_i to p_i closer to the explicit mental budgeting benchmark. In practice, this result means that consumption of larger spending categories exerts more mental-accounting type behavior. On the other hand, consumption of a good with a small spending share may not exert as much mental-accounting type behavior. In fact, part (v) of Proposition 5 shows that the degree of mental accounting behavior $\omega_i \to 0$ when $\mu_i/\kappa_i \to 0$. That is, the narrow thinker's behavior converges to the standard consumer theory when the expenditure share of good i is very small.

Part (iii) of Proposition 5 shows that, if other selves' signals about p_i are more noisy, the degree of mental accounting behavior ω_i becomes larger. Similar to part (ii) of Proposition 2, this prediction is independent from the exact psychological foundations of $\lambda_{j,i}$ discussed above. As long as different consumption decisions are made based on more distant mental states (potentially driven by bounded recall, more selective retrieval from memory, or less precise cognition), the degree of mental accounting will be higher.

These foundations, however, are helpful if one wants to predict when $\lambda_{j,i}$ is lower. For example, consider the endogenous narrow thinking framework introduced in Section 5 below and studied in detail in Appendix F. There, I let the decision maker choose endogenously what information each decision is based upon and study its implication for $\lambda_{j,i}$ and the degree of mental accounting ω_i. If the price of good i is less volatile (a lower $\sigma^2_{p_i}$), other selves will choose to know less about p_i (a lower $\lambda_{j,i}$), since the utility loss from narrow thinking is smaller. This will lead to a larger degree of mental accounting (a larger ω_i). Moreover, a more cognitively constrained decision maker, who can be interpreted as having a larger cognitive cost ϕ in the endogenous narrow thinking problem, will also have a lower $\lambda_{j,i}$ and display more mental accounting behavior.

As another example, noises in other selves' signals about p_i may come from selective retrieval from memory. Since retrieval from memory is often triggered by similarity, a natural prediction is that a self j knows more about p_i ($\lambda_{j,i}$ is higher) if good j shares common attributes with good i. In this case, the decision maker will behave as if she assigns goods with similar attributes to the same mental account but has separate mental accounts for goods with different attributes. This prediction is aligned with Evers and Imas (2019).

Finally, part (iv) of Proposition 5 establishes a limit result about when the narrow thinker's behavior converges to the explicit budgeting model. This is similar to Lemma 2 in Section 3. Specifically, the condition $\{\lambda_{j,i} \to 0\}_{j \neq i}$ means that other selves' signals about p_i are infinitely noisy and other consumption $\{x_j\}_{j \neq i}$ does not respond to p_i. The condition $\frac{\mu_y}{\kappa_y} \to 0$ means that the adjustment of y is also irrelevant in determining the response of x_i to p_i. Together, the narrow thinker's behavior converges to the explicit budgeting model, in which only x_i responds to p_i. Rigorously speaking, in this limit, $\hat{p}_i + \hat{x}_i^{\text{Narrow}} = O^2\left(\{\hat{p}_k\}_{k \in \{1, \cdots, N\}}\right)$, where $O^2(\cdot)$ denotes second or higher order terms. In practice, this result means that a decision maker with little savings and limited mental capacities to track other prices may behave as if she has an explicit budget.

Magnitudes of the degree of mental accounting behavior. The model is stylized, but it is useful to consider a simple calibration exercise about the degree of mental accounting behavior ω_i to illustrate the quantitative potential of narrow thinking. The formula for ω_i in (21) is rather complicated. The following corollary provides a simpler lower bound for ω_i.

Corollary 2 *Assume common κ and λ, that is, for all i and $j \neq i \in \{1, \cdots, N\}$, $\kappa_i = \kappa_y = \kappa$ and $\lambda_{j,i} = \lambda$. We have:*

$$\omega_i \geq 1 - \frac{\left(\lambda \frac{\mu_x}{\mu_y}\left(1 - \frac{\mu_i}{\mu_x}\right) + 1\right)\left(\frac{\mu_x}{\mu_y} + 1\right)}{\left((1-\lambda)\frac{\mu_i}{\mu_x}\frac{\mu_x}{\mu_y} + \lambda\frac{\mu_x}{\mu_y} + 1\right)\left(\frac{\mu_x}{\mu_y}\left(1 - \frac{\mu_i}{\mu_x}\right) + 1\right)} = \underline{\omega}_i, \tag{22}$$

where $\mu_x = \sum_{i=1}^N \mu_i$ captures the total expenditure share.

(22) provides a lower bound for the degree of mental accounting. The lower bound $\underline{\omega}_i$ is given by a function of three sufficient statistics: the degree of narrow thinking λ, the expenditure-saving ratio $\frac{\mu_x}{\mu_y}$, and the share of spending on good i in total expenditure $\frac{\mu_i}{\mu_x}$.

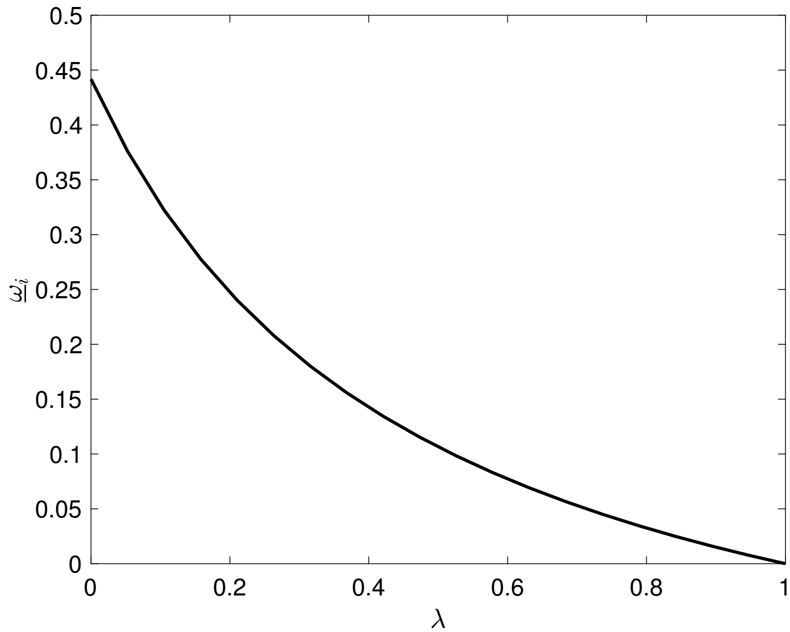

Figure 1: The lower bound on the degree of mental accounting.

I calibrate the expenditure-saving ratio $\frac{\mu_x}{\mu_y} \approx 5.8$ based on the ratio between the median household's consumption and net saving from Baker (2018).[21] I consider i with a spending share $\frac{\mu_i}{\mu_x} = 0.2$. For example, this is approximately the median spending share for food across the world (based on World Bank WDI). In Figure 1, I plot the lower bound $\underline{\omega}_i$ as a function of λ. The narrow thinker can display a sizable degree of mental accounting behavior.

One remaining challenge is to calibrate the degree of narrow thinking, λ. It is not an easy problem, but I provide two different approaches that may help. First, one could calibrate λ based on the psychological foundations of narrow thinking discussed above. For example, one interpretation of λ is that it captures how much each self can recall about prices of other goods.[22] I can then use the psychological evidence on the forgetting curve to calibrate λ. Based on the famous Ebbinghaus forgetting curve (Ebbinghaus, 1885), a decision maker retains around 25% of information after a five-day interval, which implies $\lambda = 25\%$. As another example, consider the interpretation of λ as capturing imprecise perception (Khaw, Li and Woodford, 2020; Woodford, 2020). Based on the variance of food price CPI and the variance of the noisy cognition in Woodford

[21] Baker (2018) has high-quality measures based on consumption and net saving from Linked Financial Account Data. He also re-weights his data to match the distribution of household characteristics in the United States. Based on Table 2 of Baker (2018), the median household's spending is \$57480. The median household's net saving (excluding illiquid housing) is at most \$9990. Together, they imply the expenditure-saving ratio $\frac{\mu_x}{\mu_y} \approx 5.8$.

[22] Note that, for $j \neq i$, $E\left[E_j\left[\hat{p}_i\right]|\hat{p}_i\right] = \lambda \hat{p}_i$. As a result, one interpretation of λ is how much self i can recall about shocks to p_k.

(2020), we have $\lambda = 23\%$.[23][24] Second, as mentioned above, one can infer λ based on the difference between the narrow thinker's demand elasticity estimated based on temporary price shocks and the narrow thinker's demand elasticity estimated based on persistent price differences (see Appendix B for more discussion).

Excess sensitivity to own-price changes. I now directly compare demand elasticities of the narrow thinker with standard consumer theory. This comparison shows how the smooth model of mental accounting in Proposition 4 can help explain the excess sensitivity to own-price changes documented in the literature, e.g., Hastings and Shapiro (2013).

Corollary 3 *For each good i such that $\kappa_i > 1$, the narrow thinker's consumption x_i decreases (increases) more in response to positive (negative) shocks to p_i :*

$$\frac{\partial \hat{x}_i^{\text{Narrow}}}{\partial \hat{p}_i} < \frac{\partial \hat{x}_i^{\text{Standard}}}{\partial \hat{p}_i} < 0.$$

To see the mechanism behind the excess sensitivity, note that, for a good with relatively inelastic demand ($\kappa_i > 1$), an increase in p_i will decrease the consumption of other goods, x_j (both in standard consumer theory and under narrow thinking). This is because, when $\kappa_i > 1$, the income effect of p_i on x_j (negative) will dominate the substitution effect of p_i on x_j (positive). The indirect effect through the decrease of x_j then positively influences x_i. This positive indirect effect works in the opposite direction to the negative direct effect of p_i on x_i. Under narrow thinking, the indirect effect from the coordinated response of x_j is dampened. The narrow thinker then exhibits excess sensitivity to own-price changes.[25]

For example, consider an increase in the food price. Under standard consumer theory, the decision maker can coordinate all her decisions by decreasing other consumption to smooth out the drop in food consumption. Under narrow thinking, however, other consumption will decrease less, and food consumption will decrease more.

One can also directly see the result through the lens of Proposition 4. For a good with a relatively inelastic demand ($\kappa_i > 1$), $-1 < \frac{\partial \hat{x}_i^{\text{Standard}}}{\partial \hat{p}_i}$. On the other hand, from (18), it is always

[23] I calibrate $\sigma_{p_i} \approx 0.039$ based on the standard deviation of (the log of) the monthly food price CPI ("CPIFABSL" in FRED) in 2010s. I use Woodford (2020) to calibrate the standard deviation of the noise in cognition $\sigma_{j,i} = 0.07$ (similar to here, the mental encoding in Woodford (2020) happens in the log space of the fundamental). Together, these values imply $\lambda = 23\%$.

[24] Note that noisy perception is an additional friction even if the prices of other goods are in the decision maker's memory. Combining noisy cognition and bounded recall may lead to an even larger degree of narrow thinking (an even smaller λ).

[25] The key behind this result is: when self i decides on how consumption x_i responds to shock in p_i, the impact from the adjustment of other consumption is smaller than in the standard consumer theory counterpart. This can also happen, for example, because it does not occur to self i that the adjustment of other consumption can help smooth out the impact on x_i. Those explanations are certainly plausible, but haven not been emphasized because I want to maintain the standard solution concept in Proposition 1.

the case that $\frac{\partial \hat{x}_i^{\text{Explicit}}}{\partial \hat{p}_i} = -1$. Since the narrow thinker's own-price demand elasticity is a weighted average between the two, narrow thinking leads to excess sensitivity to own-price changes. In fact, narrow thinking can significantly increase the own-price demand elasticity of a good with an inelastic demand. For example, consider a good with $\frac{\partial \hat{x}_i^{\text{Standard}}}{\partial \hat{p}_i} = -0.1$. Based on the calibration of (22) above with $\lambda = 25\%$, we have $\frac{\partial \hat{x}_i^{\text{Narrow}}}{\partial \hat{p}_i} \leq -0.3$. This elasticity is three times the elasticity in standard consumer theory $\frac{\partial \hat{x}_i^{\text{Standard}}}{\partial \hat{p}_i}$.

For a good with a relatively elastic demand ($\kappa_i < 1$), instead, the narrow thinker's consumption x_i decreases less in response to an increase in p_i.[26] That is, $\frac{\partial \hat{x}_i^{\text{Standard}}}{\partial \hat{p}_i} < \frac{\partial \hat{x}_i^{\text{Narrow}}}{\partial \hat{p}_i}$. This is because an increase in p_i now increases the consumption of other goods, x_j, since the substitution effect of p_i on x_j (positive) now dominates the income effect of p_i on x_j (negative). A increase in x_j will then further decrease x_i. In this case, the indirect effect (negative) works in the same direction as the direct effect (negative). A dampening of the indirect effect under narrow thinking then leads to under-reaction.

Testable predictions of narrow thinking. Similar to the discussion in Section 3, besides the comparative statics in Proposition 5, the narrow thinking approach to mental accounting generates two other testable predictions. First, similar to Proposition 3, mental-accounting type behavior only happens in response to temporary price shocks. The narrow thinker's behavior in response to persistent price differences should be closer to standard consumer theory. There is also evidence supporting this prediction in the daily labor supply application further discussed below.

Second, for a narrow thinker, mental accounting type behavior arises when different decisions are made separately, based on different states of mind. If a group of decisions are made together by the same self, the decision maker will be able to coordinate them better. See Appendix C for more analysis for this case in which a single self is in charge of a group of decisions.

Differences from Koszegi and Matejka (2020). Koszegi and Matejka (2020) provide another information-based theory of mental accounting. There are four main differences from my approach. First, they stay within the rational inattention paradigm: different decisions are based on the same, imperfect, information. Under narrow thinking, different decisions are based on different, non-nested, information. Second, they focus on providing conditions about when the decision maker endogenously chooses to behave as the explicit budgeting model in (18). My approach instead focuses on providing a smooth model of mental accounting. I also generate new predictions about what influences the degree of mental accounting behavior. Third, they consider quasi-linear cases where the interaction across different consumption decisions comes from the

[26] When $\kappa_i = 1$, the utility for good i becomes the log utility. In this case, $\frac{\partial \hat{x}_i^{\text{Standard}}}{\partial \hat{p}_i} = \frac{\partial \hat{x}_i^{\text{Narrow}}}{\partial \hat{p}_i} = \frac{\partial \hat{x}_i^{\text{Explicit}}}{\partial \hat{p}_i} = -1$. That is, even in standard consumer theory, the consumer behaves as if she has an explicit budget for good i. So does the narrow thinker.

complementarity/substitutability embedded in the utility function. Here, the interaction across different decisions instead comes from the budget constraint. This setting helps me provide a more direct formalization about the violation of the fungibility principle, as in Lemma 3. Fourth, more broadly, I connect mental accounting with narrow bracketing behavior.[27]

4.2 Other Mental Accounting Phenomena

I now show how narrow thinking can help explain other mental-accounting type behavior documented in the literature, such as under-reaction to taste shocks, the label effect, and the small wage elasticity to labor supply. Through these applications, I also want to illustrate another point: depending on the environment, narrow thinking can translate into either over- or under-reaction relative to the frictionless benchmark. A rule of thumb is: when the indirect effect from the coordinated response of other decisions works in the same direction as the direct effect, a dampening of the indirect effect under narrow thinking leads to under-reaction; when the indirect effect works in the opposite direction of the direct effect, a dampening of the indirect effect under narrow thinking leads to over-reaction. This rule has already been applied in the discussion after Corollary 3 and will be formalized in Proposition 11 in Appendix D.

Under-reaction to taste shocks. Another behavior associated with mental accounting is under-reaction to taste shocks. Consider an example in Heath and Soll (1996). A consumer goes to a store, wanting to buy a pair of trousers. She realizes that she does not like any trousers in the store (a negative taste shock), but still chooses to buy a pair. To see how this behavior is connected to mental accounting, notice that with explicit budgets in (18), the consumption of a good is insensitive to the taste shock.

Narrow thinking can provide a smooth model for this behavior. To formalize, let me add taste shocks in the environment in Section 4.1. The decision maker's utility is given by

$$\sum_{i=1}^{N} \varphi_i v_i\left(x_i\right) + h\left(y\right), \tag{23}$$

where $v_i\left(x\right)$ and $h\left(y\right)$ are the same as in Section 4.1. Here I introduce taste shocks. $\varphi_i \sim \log \mathcal{N}\left(\log \bar{\varphi}_i, \sigma^2_{\varphi_i}\right)$ parameterizes the taste for good i. The decision maker still needs to satisfy the budget constraint, $\sum_{i=1}^{N} p_i x_i + y \leq w$. Since I am interested in responses to taste shocks, I treat w and all p as constants.

Similar to Section 4.1, I consider the following narrow thinker: each self $i \in \{1, \cdots, N\}$ of the narrow thinker, who is in charge of purchasing good i, perfectly knows its taste φ_i, but receives

[27] On another note, Galperti (2019) provides a model of mental accounting based on self-control concerns.

a noisy signal about each of the other φ_k: $s_{i,k} = \varphi_k \epsilon_{i,k}$, with $\epsilon_{i,k} \sim \log \mathcal{N}\left(0, \sigma_{i,k}^2\right)$ and $\sigma_{i,k}^2 > 0$. Finally, similar to (7), I define the narrow thinker's (log) demand function as $\hat{x}_i^{\text{Narrow}}\left(\hat{\varphi}_1, \cdots, \hat{\varphi}_N\right) \equiv E\left[\hat{x}_i^*\left(s_i\right) | \hat{\varphi}_1, \cdots, \hat{\varphi}_N\right].$

Proposition 6 *For each good i, the narrow thinker's consumption x_i increases (decreases) less in response to positive (negative) taste shocks to φ_i : for $i \in \{1, \cdots, N\}$,*

$$\frac{\partial \hat{x}_i^{\text{Standard}}}{\partial \hat{\varphi}_i} > \frac{\partial \hat{x}_i^{\text{Narrow}}}{\partial \hat{\varphi}_i} = \omega_i \frac{\partial \hat{x}_i^{\text{Explicit}}}{\partial \hat{\varphi}_i} + \left(1 - \omega_i\right) \frac{\partial \hat{x}_i^{\text{Standard}}}{\partial \hat{\varphi}_i} > 0, \tag{24}$$

where the demand with explicit budgeting x_i^{Explicit} is still given by (18) and the weight $\omega_i \in [0,1]$ is still given by (21).

Proposition 6 shows that, in response to shocks to φ_i, the narrow thinker's demand x_i^{Narrow} is given by a weighted average between demand in standard consumer theory (x_i^{Standard}) and demand with explicit budgeting (x_i^{Explicit}). The intuition is similar to Subsection 4.1. In standard consumer theory, the response of x_i to φ_i crucially depends on the indirect effects from the coordinated response of other x_j. Under narrow thinking, other selves will not respond much to φ_i. The response of x_i to φ_i is then closer to the explicit budgeting model, in which each decision can be made in isolation. Remarkably, the weight on x_i^{Explicit}, which captures the degree of mental accounting behavior, shares the *same* formula of (21). In other words, the comparative statics results about what drives the degree of mental accounting in Proposition 5 still apply here.

Proposition 6 further establishes that the narrow thinker under-reacts to taste shocks compared to standard consumer theory. To better understand the intuition behind the under-reaction, consider a positive taste shock to φ_i. Under standard consumer theory, an increase in φ_i not only increases x_i (a positive direct effect) but also decreases the consumption of other goods x_j. The coordinated decrease of other consumption x_j further increases x_i (a positive indirect effect). The indirect effect then works in the same direction as the direct effect. Under narrow thinking, the indirect effect from the coordinated response of x_j is dampened. The narrow thinker then under-reacts to taste shocks.

The label effect. The same mechanism can also explain another behavior connected to mental accounting, "the label effect" (Beatty et al., 2014; Benhassine et al., 2015; Abeler and Marklein, 2016; Hastings and Shapiro, 2018). For example, Beatty et al. (2014) study the UK Winter Fuel Payment program. Despite its label, the fuel payment is in fact a cash transfer and there is no obligation to spend any of the payment on fuel despite the label. Beatty et al. (2014) nevertheless find that households increase their fuel consumption excessively after receiving the Winter Fuel Payment. To see how this behavior is connected to mental accounting, notice that, in the explicit budgeting model in (18), if the decision maker views the fuel payment as part of the budget w_i allocated for fuel, she should spend all the payment on fuel consumption.

Narrow thinking can provide a smooth model for this behavior. To formalize, consider the environment in Section 4.1. That is, the consumer's utility is given by (13). The decision maker is subject to the budget constraint $\sum_{i=1}^{N} x_i + y \leq w + \sum_{i=1}^{N} w_i$, where w is the decision maker's generic wealth (a constant) and w_i captures the part of the budget that is labelled for the consumption of good i, e.g., the winter fuel payment in Beatty et al. (2014) and the beverage voucher in Abeler and Marklein (2016). For the narrow thinker, each self $i \in \{1, \cdots, N\}$, who is in charge of purchasing good i, perfectly knows $w_i \sim \log \mathcal{N}\left(\bar{w}_i, \sigma_{w_i}^2\right)$, but receives a noisy signal about each of the other w_k: $s_{i,k} = w_k \epsilon_{i,k}$, with $\epsilon_{i,k} \sim \log \mathcal{N}\left(0, \sigma_{i,k}^2\right)$ and $\sigma_{i,k}^2 > 0$. This information structure captures the idea that the decision maker has the winter fuel payment at the front of her mind when purchasing fuel, but not necessarily when making other purchases.

Now I show how the narrow thinker's consumption of each good i, x_i, is excessively sensitive to w_i. Similar to (7), I define the narrow thinker's (log) demand function as $\hat{x}_i^{\text{Narrow}}\left(\hat{w}_1, \cdots, \hat{w}_N\right) \equiv E\left[\hat{x}_i^*\left(s_i\right)|\hat{w}_1, \cdots, \hat{w}_N\right].$

Proposition 7 *The narrow thinker's consumption x_i increases (decreases) more in response to positive (negative) shocks to w_i :*

$$\frac{\partial \hat{x}_i^{\text{Narrow}}}{\partial \hat{w}_i} = \omega_i \frac{\partial \hat{x}_i^{\text{Explicit}}}{\partial \hat{w}_i} + (1-\omega_i)\frac{\partial \hat{x}_i^{\text{Standard}}}{\partial \hat{w}_i} > \frac{\partial \hat{x}_i^{\text{Standard}}}{\partial \hat{w}_i} > 0 \quad \forall i,$$

where the weight $\omega_i \in [0,1]$ is still given by (21).

Similar to Propositions 4 and 6, Proposition 7 shows that, in response to shocks to w_i, the narrow thinker's demand x_i^{Narrow} is given by a weighted average between the demand in standard consumer theory (x_i^{Standard}) and the demand with explicit budgeting (x_i^{Explicit}). Here, by explicit budgeting, I mean that the consumer uses the entirety of w_i on the consumption of good i. This smooth model of mental accounting then leads to the excess sensitivity of the consumption x_i to w_i. This smooth model is also consistent with the evidence in Beatty et al. (2014), which find that consumers spend a large portion, but not all, of the winter fuel payment on fuel consumption.[28]

To further understand the intuition behind the excess sensitivity, note that in standard consumer theory an increase in w_i will increase the consumption of both x_i (a positive direct effect) and other consumption x_j. The increase in other consumption x_j then decreases x_i (a negative indirect effect). The indirect effect works in the opposite direction of the direct effect, and the dampening of the indirect effect under narrow thinking leads to over-reaction.

[28]The finding of Abeler and Marklein (2016) is similar and also consistent with such a smooth model.

The small wage elasticity of daily labor supply. Another behavior often connected to mental accounting is the small wage elasticity of daily labor supply (Camerer et al., 1997; Farber, 2015; Thakral and To, 2020). In standard labor supply theory, when the wage on a particular day increases, the decision maker not only increases her labor supply on the day of the wage increase, but also decreases her labor supply on other days. This coordinated response further increases the labor supply on the day of wage increase and generates a large elasticity of daily labor supply. On the other hand, in an explicit income targeting model (Camerer et al., 1997), the decision maker assigns an income target for each day. In this case, the decision maker exhibits a negative wage elasticity of daily labor supply. Under narrow thinking, the decision maker's wage elasticity of daily labor supply is a weighted average between the two cases. This prediction is consistent with the empirically documented positive, but small, wage elasticity of daily labor supply (e.g., Farber, 2015). Moreover, in line with Proposition 3, the smaller wage elasticity of labor supply under narrow thinking is about the response to temporary daily wage shocks. In fact, Fehr and Goette (2007) and Angrist, Caldwell and Hall (2021) find a larger wage elasticity of labor supply based on wage variations at longer frequencies. See Appendix C for details.

5 Additional Applications and Extensions

In this section, I study how narrow thinking can help explain two other types of narrow bracketing behavior: myopic loss aversion and the neglect of "adding-up" effects. I illustrate how these phenomena are deeply connected to the unifying theme of the paper, the decision maker's difficulty coordinating her decisions. At the end, I also provide a framework to endogenize narrow thinking: in this problem, besides making multiple decisions, the decision maker also chooses what information each decision is based upon, subject to a cognitive cost.

Myopic loss aversion. One behavior often connected to narrow bracketing is the decision maker's aversion to combining small and favorable gambles (Samuelson, 1963). The existing explanations of this behavior, such as Benartzi and Thaler (1995), Barberis, Huang and Thaler (2006), and Rabin and Weizsacker (2009), contains two elements: first, the decision maker suffers from loss aversion; second, she decides on each gamble in isolation.[29] Narrow thinking provides a formal explanation of myopic loss aversion, without directly requiring the decision maker to decide on each gamble in isolation.

Let me briefly summarize the analysis here (see Appendix E for details). I consider a decision maker with loss aversion. She faces two gambles. For each gamble, there is a 50% chance that it

[29] Loss aversion alone is not enough, since the decision maker can combine independent and favorable gambles to avoid the loss.

turns out to be a loss of \$1, and a 50% chance that it turns out to be a gain of $\$\left(1+\mu_i\right)$, where $\mu_i > 0$ is a random variable. Whether each gamble turns out to be a gain or a loss is independent of the other gamble. The benefit of combining two gambles is, if one gamble turns out to be a loss and another gamble turns out to be a gain, the decision maker who combines them will not suffer from loss aversion. In fact, for a frictionless decision maker, she will coordinate her gambling decisions such that she either invests in two gambles together or does not invest in any of them.

For a narrow thinker, however, each self $i \in \{1, 2\}$ only knows the return of her gamble μ_i. She does not perfectly know the return of the other self's gamble μ_{-i}. Two selves cannot perfectly coordinate their gambling decisions. This difficulty in coordinating decisions makes it harder for the narrow thinker to enjoy the benefits of combining two gambles. Together, this leads to a lower probability of investing in each gamble and provides a model of myopic loss aversion.[30]

Consistent with the discussion in previous sections, a testable prediction of the narrow thinking approach to myopic loss aversion is: the decision maker will be more reluctant to gamble if she makes different gambling decisions separately, based on different states of mind. This prediction is consistent with the finding in Redelmeier and Tversky (1992). They find that, when participants make several gambling decisions sequentially, they are less willing to gamble than when they make these gambling decisions together.

Neglect of "adding-up" effects. Another behavior often connected to narrow bracketing is the neglect of "adding-up" effects (Read, Loewenstein and Rabin, 1999). Consider the decision to smoke. The health consequence of a cigarette is small, but the cumulative health consequences of smoking can be large (i.e., the "adding-up" effects). Moreover, the cumulative benefit of smoking increases much more slowly than the cumulative costs. If the decision maker can perfectly coordinate all her smoking decisions, she will not smoke much. However, in practice, the decision maker decides how much to smoke on different occasions separately and may face difficulties in coordinating her smoking decisions.

Let me briefly summarize how the narrow thinker may smoke excessively because she neglects the adding-up costs of smoking (see Appendix E for details). I consider a decision maker who faces a convex cost based on total smoking. For the narrow thinker, each self is in charge of the smoking decision on one occasion and knows how attractive it is to smoke on that occasion, but does not perfectly know about the attractiveness on other occasions. When smoking becomes more attractive, the narrow thinker under-estimates how other selves will increase smoking, neglects the adding-up costs, and smokes excessively.

Mathematically, this application is different from those in Sections 3 – 4. Here I study the impact of a common shock to the attractiveness of smoking on all occasions. More generally, in

[30] Mathematically, this application is different from those in Sections 3 – 4 because each self's gambling decision is discrete.

response to common shocks to the fundamental, if different selves' decisions are strategic substitutes, narrow thinking leads to overreaction relative to the frictionless benchmark. This case arises when the decision maker faces convex add-up costs (e.g., smoking) or concave add-up benefits (e.g., diminishing marginal utility). On the other hand, if different selves' decisions are strategic complements, narrow thinking leads to under reaction relative to the frictionless benchmark. This case arises when the decision maker faces convex add-up benefits (e.g., skill acquisition) and concave add-up costs (e.g., habituation).[31]

Endogenous narrow thinking. The previous analysis lets different decisions be made based on different, but exogenous, information. Here, I provide a framework to endogenize such information. In this problem, besides making the multiple-decisions, the decision maker also chooses what information each decision is based upon, subject to a cognitive cost. This problem studies the optimal information choice problem at the *decision*-level, going beyond the standard rational inattention paradigm.

As in Section 2, let $(S, \mathcal{F}, P)$ be the underlying probability space. The decision maker's utility is given by $u\left(\vec{x}, \vec{\theta}\right)$, where u is twice continuously differentiable and strictly concave over $x \in \mathcal{X}_1 \times \cdots \times \mathcal{X}_N$ and $\mathcal{X}_i$, a convex set on $\mathbb{R}$, denotes the set of possible decisions x_i. The payoff relevant fundamental, $\vec{\theta}$, is the realization of an exogenously drawn random vector $\vec{\boldsymbol{\theta}}$: $S \to \Theta$, where $\Theta \subseteq \mathbb{R}^M$ denotes the set of possible fundamentals. Here, for clarity, I use bold letters to denote random variables and normal letters to denote their realizations.

I then use s_i to denote the signal (potentially multi-dimensional) under which each decision i is made. s_i is the realization of a random vector $\boldsymbol{s_i}$: $S \to \Omega_i$, where Ω_i denotes the set of possible signal realizations for decision i. The decision maker now endogenously chooses $\boldsymbol{s_i}$, which summarizes how decision i's signal is generated, from a set of random vectors $\boldsymbol{\Omega_i}$.

Specifically, the decision maker jointly chooses the information upon which each decision is made $\{\boldsymbol{s_i} \in \boldsymbol{\Omega_i}\}_{i=1}^N$, and the decision rules $\{x_i(\cdot): \Omega_i \to \mathcal{X}_i\}_{i=1}^N$. She maximizes her expected utility, subject to a cognitive cost of acquiring knowledge about the fundamental:

$$\max_{\{\boldsymbol{s_i} \in \boldsymbol{\Omega_i}, x_i(\cdot)\}_{i=1}^N} E\left[u\left(x_1(s_1), \cdots, x_N(s_N), \vec{\theta}\right)\right] - \phi \sum_{i=1}^N I\left(\boldsymbol{s_i}; \vec{\boldsymbol{\theta}}\right). \tag{25}$$

In (25), $I\left(\boldsymbol{s_i}; \vec{\boldsymbol{\theta}}\right)$ denotes the mutual information between decision i's signal $\boldsymbol{s_i}$ and the fundamental $\vec{\boldsymbol{\theta}}$, which equals the entropy reduction $H\left(\vec{\boldsymbol{\theta}}\right) - H\left(\vec{\boldsymbol{\theta}}|\boldsymbol{s_i}\right)$. Then, $\phi I\left(\boldsymbol{s_i}; \vec{\boldsymbol{\theta}}\right)$ captures the cognitive cost of self i's acquired knowledge about the fundamental, where ϕ parameterizes how

[31] This relationship between strategic complementarity/substitutability and under-/over-reaction under narrow thinking only holds in response to a common shock. If the shock is idiosyncratic, as in Sections 3 – 4, we should rely on Proposition 11 in Appendix D to predict whether narrow thinking leads to over-reaction or under-reaction in a given environment.

costly it is for the decision maker to acquire information about the fundamental.

This problem can be decomposed into two sub-problems. The first is about how decisions are made *given* the chosen information $\{\boldsymbol{s_i}\}_{i=1}^N$. This sub-problem is the *same* as the one studied in Section 2, and the optimal decision rule can be characterized by (3). The second regards choosing the optimal information $\{\boldsymbol{s_i} \in \boldsymbol{\Omega_i}\}_{i=1}^N$ for each decision i, subject to the cognitive cost. The problem in (25) then has the following interpretation. The decision maker first chooses $\{\boldsymbol{s_i}\}_{i=1}^N$, i.e., how each self i's signal is generated, subject to the cognitive cost. Given the information structure $\{\boldsymbol{s_i}\}_{i=1}^N$, different selves play the equivalent incomplete information Bayesian game defined in Proposition 1.

It is worth highlighting how the problem in (25) differs from the canonical rational inattention and sparsity paradigms. There, the decision maker decides what information about the fundamental to acquire subject to a cognitive cost, but different decisions can share this information. The optimal information choice problem is at the *decision maker* level. Here, the information is decision specific, and the optimal information choice problem is at the *decision* level. The problem captures the idea that, when the decision maker makes a particular decision, she cannot effortlessly use/recall the information used for other decisions.

The analysis of the problem in (25) is nontrivial. For the problem to be analytically solvable, one can consider a quadratic or log-quadratic approximation of the utility function and restrict fundamentals and signals to be normally or log-normally distributed. In Appendix F, I first revisit the simple consumer theory in Section 3. There, I do not directly impose that each self i has perfect knowledge of the price of the good she buys, p_i. I instead show that each self i endogenously chooses to know more about p_i. In this sense, narrow thinking can arise endogenously. I then study a general problem in which I allow the signals to depend on the fundamental flexibly. The general insight is similar: since different decisions are based on different decision rules, each self is "interested in" different parts of the fundamental; it is then optimal for different selves' signals to take different forms, and narrow thinking arises endogenously. Finally, I show how, once I endogenize the degree of narrow thinking, I can generate new predictions about what drives the degree of narrow bracketing and mental accounting in Propositions 2 and 5.

6 Conclusion

Each decision maker faces multiple economic decisions and makes these decisions separately. Nevertheless, in standard modeling practice, we implicitly assume perfect self-coordination among all these decisions. It is as if the decision maker determines all her decisions together. In this paper, I try to break such perfection coordination. I develop an approach, narrow thinking, to capture the decision maker's difficulty in coordinating her multiple decisions. The notion of narrow thinking is that different decisions are based on different, non-nested, information. This notion is motivated by the psychological observation that the decision maker may not incorporate all the relevant information when making each decision. Under narrow thinking, the decision maker makes each decision with imperfect knowledge of other decisions. This friction effectively attenuates the interaction across decisions, and the decision maker "narrowly brackets." I then show how narrow thinking provides a unified explanation of multiple behavioral phenomena, such as mental accounting, myopic loss aversion, and the neglect of "adding-up" effects. It also generates new predictions about what drives the degree of frictional behavior, such as the degree of mental accounting. In a companion work, Lian (2020) studies the decision maker's difficulty in coordinating her decisions intertemporally.

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