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Inflation perception and behavior: Novel experimental and macroeconomic analyses

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Avertissement

La Faculté n'entend donner aucune approbation ni improbation aux opinions émises dans cette thèse ; ces opinions doivent être considérées comme propres à leur auteur.

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Abstract

This thesis seeks to understand how economic agents—primarily household consumers—behave when faced with inflation. I examine how individuals perceive inflation and adapt their consumption and savings decisions accordingly. Given the inconsistent results in the existing literature on the inflation-consumer relationship, I develop and apply novel techniques to gain new perspectives both at the micro- and macroeconomic levels. I develop an experimental task to measure how subjects internalize and ultimately react to inflation. This experimental work provides a direct link between measures perceived and expected inflation and subsequent consumption and savings behavior. Using this finding, I can compare subjects' performance and adaptability to their individual characteristics to better understand the underlying traits that correlate with decision-making in inflation. In particular, numerical abilities, consistency of economic decision-making, and general adaptability are strong predictors of task performance. Further, through different financial education treatments, I identify effective means of educating consumers on appropriate decision-making in inflationary conditions—particularly by providing personalized feedback and easily actionable advice. Finally, through wavelet analysis, I demonstrate how the inconsistent expectations-consumption relationship found in the literature may in fact arise from an underlying cyclical nature. Moreover, I find supporting evidence of the positive relationship between expectations and nondurables consumption at the macro-level as identified at the individual level through my experimental methods.

Keywords

Inflation, Experimental economics, Behavioral economics, Wavelet analysis, Financial education

Perception d'inflation et comportement des agents : Nouvelles analyses expérimentales et macroéconomiques

Résumé

Cette thèse cherche à comprendre comment les agents économiques, surtout les ménages, se comportent face à l'inflation. Elle s'intéresse à la manière dont les individus perçoivent l'inflation et adaptent leurs décisions économiques à son évolution. Étant donné l'incohérence des résultats de la littérature sur la relation inflation-comportement des ménages, je développe et applique de nouvelles techniques afin d'offrir de nouvelles perspectives tant à l'échelle individuelle que macroéconomique. Je développe une tâche expérimentale pour mesurer comment les participants intériorisent et réagissent à l'inflation. Ces expériences relient directement leurs perceptions et anticipations à leurs comportements. Je compare les performances des participants dans la tâche à leurs caractéristiques individuelles pour identifier celles qui influencent le comportement ; notamment les capacités numériques, la cohérence des choix économiques, et l'adaptabilité sont des bons prédicteurs de la performance. En outre, à travers différents traitements d'éducation financière, j'identifie des moyens efficaces d'éduquer les ménages à leur prise de décision face à l'inflation, notamment en fournissant des informations personnalisées et des conseils facilement appliqués. Finalement, à travers une analyse par ondelettes, je montre que l'incohérence de la relation anticipations-consommation observée dans la littérature peut être le résultat d'une nature cyclique sous-jacente. De plus, je mets en évidence à l'échelle macroéconomique une relation positive entre les anticipations et la consommation des bien non-durables similaire à celle obtenue à l'échelle individuelle par ces méthodes expérimentales.

Mots-clés

Inflation, Économie expérimental, Économie comportementale, Analyse par ondelettes, Éducation financière

Résumé substantiel

Ma thèse de doctorat se compose de trois chapitres qui partagent l'objectif principal de mieux comprendre le comportement des agents – particulièrement, les individus consommateurs – face à l'inflation. La motivation principale qui justifie cette analyse du lien entre l'inflation et le comportement des individus est que la littérature offre des résultats conflictuels d'un point de vue soit théorique, soit empirique. Par conséquent, dans ma thèse, je développe et applique de nouvelles techniques afin d'offrir de nouvelles perspectives tant à l'échelle individuelle que macroéconomique.

Une meilleure compréhension des liens entre la manière dont les individus perçoivent et anticipent l'inflation et leur comportement pourrait, tout d'abord, contribuer à la théorie économique et améliorer la conduite de la politique monétaire. Cependant, d'un point de vue plutôt pratique, l'inflation constitue une menace pour les ménages et leur bien-être financier, donc l'objet de ma recherche consiste aussi à identifier des manières efficaces d'éduquer les individus à mieux gérer leurs décisions financières face à la hausse des prix.

Compte tenu des méthodes d'enquêtes à l'échelle macroéconomique typiquement appliquées à l'analyse du lien entre les perceptions ou les anticipations d'inflation et le comportement des individus, mon premier projet vise à générer des données à l'échelle microéconomique qui puissent établir un lien direct entre la façon dont les individus internalisent (i.e. perçoivent et anticipent) l'inflation et leurs décisions d'épargne et de consommation. Pour ce faire, j'emploie une approche d'économie expérimentale. Concrètement, je développe une nouvelle tâche expérimentale, le Jeu de l'Épargne, qui place les participants dans un environnement contrôlé par lequel nous pouvons ajuster les conditions d'inflation et observer la façon par laquelle les individus internalisent et éventuellement réagissent aux changements des prix en adaptant leurs décisions de consommation et d'épargne. Dans le champ de l'économie expérimentale, ce travail apporte une contribution originale en proposant une tâche expérimentale assez facile à implémenter pour bien simuler l'inflation en laboratoire – ou en ligne – et observer à la fois les perceptions et les anticipations des participants ainsi que leur comportement.

Le code développé pour le Jeu de l'Épargne est disponible gratuitement sur le site https://github.com/o-nate/savings-game et peut aussi être testé et exploré sur https://savingsgame.org.

Le protocole expérimental du Jeu de l'Epargne et les résultats d'une première expérience menée en ligne sont présentés dans le premier chapitre de ma thèse. Les résultats de cette expérience montrent tout d'abord que la performance moyenne des participants face à l'inflation est vraiment faible, d'autant plus faible que l'inflation varie, mais également que la performance varie en relation avec les perceptions et les anticipations de l'inflation des participants. On observe en outre une forte hétérogénéité entre leurs performances, ce qui est expliqué par certaines caractéristiques individuelles. Finalement, en testant une intervention, on n'identifie quasiment aucun impact d'un module d'explication simple de l'inflation et du taux d'intérêt, de type éducation financière traditionnelle, sur les performances des participants. De plus, les résultats montrent la validité externe du Jeu de l'Épargne, dans lequel les biais des individus observés dans la vie réelle se révèlent aussi dans la tâche expérimentale.

Mon deuxième chapitre vise à compléter ces premiers résultats dans deux directions principales, tout d'abord, faire une liaison plus claire entre les résultats expérimentaux et les données macroéconomiques de la vie réelle, et aussi proposer des méthodes d'intervention plus efficaces pour améliorer l'internalisation de l'inflation dans les décisions des participants et donc leurs performances dans la tâche. Les résultats de cette deuxième expérience qui reprend en partie le protocole du Jeu de l'Epargne sont présentés dans le second chapitre. Ils confortent les premiers résultats et apportent aussi une validation expérimentale aux méthodes d'enquête utilisées par les banques centrales pour mesurer les perceptions et les anticipations d'inflation. En outre, ils montrent que les perceptions et les anticipations qualitatives, et également l'incertitude, jouent un rôle potentiellement plus important dans la prise de décision que les perceptions et anticipations quantitatives. On montre aussi que les interventions qui rendent compte aux participants de leur performance comparée à la performance maximum possible et leur proposent des explications personnalisées et pratiques – au lieu de théoriques – parviennent à améliorer leur prise de décision. Finalement, les résultats de cette deuxième expérience démontrent aussi la reproductibilité du Jeu de l'Épargne comme tâche expérimentale.

A partir de l'ensemble de ces résultats expérimentaux, générés par une nouvelle tâche expérimentale confortée par une validité externe, j'ai choisi de m'intéresser à l'analyse de données macroéconomiques afin de chercher à identifier des tendances empiriques à l'échelle macroéconomique similaires à celles identifiées à l'échelle microéconomique par nos expériences. Étant donné les résultats conflictuels obtenus dans la littérature sur la relation entre les perceptions et anticipations d'inflation d'une part et la consommation ou l'épargne d'autre part, j'explore en même temps la nature cyclique de l'internalisation de l'inflation, plutôt les anticipations d'inflation, en lien avec le comportement de consommation et d'épargne au niveau macroéconomique. Pour ce faire, j'applique une nouvelle technique, une analyse utilisant les ondelettes, afin d'identifier et ainsi de comparer les cycles sous-jacents dans les données. Cette approche me permet de montrer que l'inconsistance des résultats observée dans la littérature peut, en effet, être une manifestation des liens cycliques entre les anticipations d'inflation et la consommation et l'épargne. Le code développé pour cette analyse et permettant d'effectuer une analyse d'ondelettes est également disponible gratuitement à l'adresse : https://github.com/o-nate/inflation-wavelets.

Dans l'ensemble, ma thèse doctorale apporte les principales contributions suivantes au domaine relativement peu exploré de l'analyse empirique du comportement des individus face à l'inflation en relation avec leurs perceptions et anticipations d'inflation. Dans le champ de l'économie expérimentale, la première contribution consiste à proposer une tâche expérimentale qui permet de générer des données à l'échelle individuelle des décisions de consommation des participants face à l'inflation ainsi que de leurs perceptions et anticipations d'inflation. Les résultats obtenus confortent le fait que les individus ont du mal à adapter leurs décisions de consommation et d'épargne à l'évolution de l'inflation, d'autant plus qu'elle est variable. Ils mettent aussi en évidence une forte hétérogénéité de leurs performances, en relation avec la qualité de leurs perceptions et anticipations d'inflation, et certaines compétences, en particulier : leurs capacités mathématiques, la cohérence de leur prise de décisions économiques, et leur adaptabilité. Cette tâche peut être facilement adaptée à d'autres questions de recherche économique liées à la prise de décision de consommation et d'épargne.

À la théorie macroéconomique et, conséquemment, à la politique monétaire, j'apporte un lien entre les anticipations d'inflation et le comportement à l'échelle microéconomique, et montre ensuite comment ces relations se manifestent également à l'échelle macroéconomique. Ainsi, en mettant cette connexion en évidence, on apporte des nuances importantes au débat empirique sur la validation de modèles macroéconomiques et, on renforce aussi, la nécessité pour la stabilité économique et pour la politique monétaire de maintenir la population informée de l'évolution de l'inflation présente et future. Enfin, je propose des recommandations expérimentalement validées de méthodes efficaces pour améliorer la compréhension de l'impact de l'inflation pour les ménages et faciliter leurs décisions de consommation et d'épargne dans un contexte inflationniste.

Comme le montre cette thèse, l'inflation pose de sérieux challenges non seulement à la recherche économique et à la conduite de la politique monétaire, mais aussi aux ménages qui éprouvent des difficultés à la prendre en compte de façon efficace dans leurs décisions de consommation et d'épargne. La recherche présentée dans cette thèse de doctorat peut contribuer à offrir de nouvelles perspectives pour construire des programmes d'éducation simples visant à aider les individus, notamment les plus fragiles, à mieux se prémunir de l'impact défavorable de l'inflation sur leur situation financière.

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Introduction

The following three research projects that compose my doctoral dissertation share the primary objective of understanding how economic agents—principally household consumers—behave when faced with inflation. The primary motivating factor to explore this relationship between inflation and consumer behavior arises because the existing literature has provided inconsistent results from both the theoretical as well as empirical perspectives (D'Acunto et al., 2022; Gautier & Montornès, 2022). Therefore, I develop and apply novel techniques in order to provide new perspectives both at the micro- and macroeconomic level on the underlying complexity of this relationship.

In particular, establishing a clearer understanding of how household consumers perceive and anticipate inflation—or *internalize inflation*—and how this internalization ultimately relates to their economic behavior can inform monetary policy and advance both micro- and macroeconomic theory. But practically speaking, inflation poses quite concrete risks to households' financial well-being, so my research further aims to identify effective means of educating household consumers on appropriate financial decision-making in inflationary conditions.

Having experienced nearly no inflation since the early 1990s, developed economies lack sufficient contemporary research on how households' behavior in inflationary conditions functions—despite the important role of inflation perceptions and expectations in macroeconomic models and central banks' ability to maintain price stability (Abildgren & Kuchler, 2021; Weber, Gorodnichenko, et al., 2023). Moreover, the contemporary literature has produced inconclusive, at times conflicting, results on the relationships between expected inflation and household behavior (Andrade et al., 2023; Binder, 2017; D'Acunto et al., 2022). For instance, Burke and Ozdagli (2021) find little impact on consumption behavior in the United States, while Dräger and Nghiem (2021), Ichiue and Nishiguchi (2015), and Andrade et al. (2023) find positive relationships in Germany, Japan, and France respectively between the inflation rate households expect and their consumption. In fact, Coibion et al. (2021) find in the US a positive relationship between expectations and nondurables consumption on the one hand and negative relationship between expectations and durables consumption on the other. Nevertheless, as Coibion et al. (2021) point out, inflation expectations and consumption decisions can be endogenous and, therefore, difficult to disentangle through macroeconomic data.

Because research investigating the relationship between inflation internalization and consumption behavior has typically employed survey-based, macroeconomic approaches (Gautier & Montornès, 2022), my first work aims to provide micro-level data that can directly connect how consumers internalize (i.e. perceive and anticipate) inflation with regard to their subsequent savings and consumption decisions. To do so, I turn to experimental economics. Specifically, I develop an experimental task, the Savings Game, that places subjects in a controlled environment through which we can adjust inflation to observe how subjects internalize and ultimately react to price changes. Within experimental economics, this work contributes an original, easily implementable task to simulate inflation in the laboratory—or online—and directly measure subjects' perceptions, expectations, and behavior. The codebase developed for the Savings Game task is freely available for use at https://github.com/o-nate/savings-game and may be freely tested and explored at https://savingsgame.org.

Chapter 1 presents the Savings Game and the results of an online experiment employing the novel task in its protocol. These results reveal that subjects on average perform poorly when faced with inflation, and that the more inflation varies, the worse they perform. Moreover, subjects' performance depends on the accuracy of their inflation perceptions and expectations. Additionally, strong heterogeneity among subject performances presents clear correlations to unique individual characteristics. Finally, in testing an intervention, traditional financial education techniques demonstrate essentially no impact by on in-task performance. Furthermore, beyond these findings, the results also demonstrate the external validity that the Savings Game offers as an experimental task, whereby the biases exhibited by subjects in real life are evident as well in-task.

My second chapter extends this work in two directions:

1. it connects more explicitly the experimental results to real-life macroeconomic data, and
2. it uncovers effective methods for educational interventions to improve inflation internalization in subjects' decision-making and, thus, performance in the task.

Chapter 2 presents this second experiment and its results. In addition to reinforcing the results from the first experiment, the results also provide experiment-based validation of the survey-based elicitation methods used by central banks to measure perceived and expected inflation. Further, the results show that qualitative internalizations as well as uncertainty play potentially more significant roles in decision-making. The results also show that interventions that provide subjects with both feedback on their performance, comparing it to the maximum they could have achieved, and personalized and easily implementable—rather than theoretical—guidance as well, demonstrably improve decision-making. Finally, this second experiment's results demonstrate the reproducibility of the Savings Game as experimental task.

With these experimental results, generated through an externally valid experimental task, I then aim to identify parallel empirical trends in macroeconomic data with those found in the micro-level experimental results. Given the inconsistency of findings throughout the existing literature on the relationship between inflation internalization and savings and consumption behavior (Andrade et al., 2023; Binder, 2017; D'Acunto et al., 2022), though, I also simultaneously explore the cyclical nature of this relationship at the macroeconomic level. To do so, I apply a novel technique known as wavelet analysis to identify and compare the underlying cycles in the data. This technique allows me ultimately to demonstrate how this inconsistency in the literature's findings is, rather, an inherent reflection of the cyclical relationships between inflation expectations and consumption and savings. The codebase developed for conducting wavelet analysis on such economic data is also freely available for use at https://github.com/o-nate/inflation-wavelets.

Taken together, my doctoral dissertation makes the following principal contributions to the relatively little-studied field of household consumers' behavior in and internalizations of inflation. First, to experimental economics, I offer an externally valid experimental task that generates micro-level data on household consumers' decision-making in inflationary conditions as well as on the relationship between their behavior and internalizations of inflation. The results obtained confirm at the microeconomic level that individuals struggle to adjust their consumption and savings behavior in inflation, particularly when inflation variance increases. They further reveal the strong heterogeneity in performance across subjects and how these differences relate to the accuracy of their inflation internalization as well as additional characteristics, in particular: numerical abilities, consistency of economic decisions, and general adaptability. This experimental task can be easily adapted to answer other research questions relating to consumption and savings decision-making.

To macroeconomic theory and, by extension, monetary policy, I provide micro-level data on the relationship between inflation expectations and behavior, and explicitly demonstrate how these patterns reveal themselves in the macroeconomic data. Drawing this connection adds significant nuance to the competing models within macroeconomic theory as well as underscores the importance for economic stability and monetary policy of keeping the general population informed of present and future inflation trends. I further this contribution by also providing experimentally tested educational methods to improve households' understanding of inflation's impact as well as their consumption and savings decision-making in inflationary contexts.

As shown throughout this work, inflation poses unique challenges not only to economic research and monetary policy, but also to household decision-makers as well. The research presented in this thesis provides novel perspectives on these challenges with the aim ultimately of improving education and decision-making for households, particularly the most economically vulnerable, to better protect themselves from the negative impacts that inflation threatens.

Chapter 1:
Inflation and behavior, an experimental analysis[1]

We experimentally analyze the impact of inflation on individuals' savings and consumption behavior as a means of linking their perceptions and expectations of inflation to their savings-consumption behavior at the individual level. People's behavioral reactions to inflation can vary significantly, and their ability to adapt their behavior to inflation appropriately can mitigate the negative impacts of rising prices. Their adaptability may be influenced by the pattern of inflation (e.g. expected or unexpected, high or low), their experience with and perception of inflation, and many other individual characteristics may affect their ability to react to and protect themselves from harmful inflationary conditions. Through an online experiment, we distinguish the underlying situational and personal factors that correlate with people's adaptability to changes in inflationary conditions, observe people's savings and consumption decision-making processes, and determine whether an intervention can improve their decisions and adaptability in such changing conditions. We develop a novel experimental task that simulates households' inflationary experience and compare subjects' performance to a benchmark best strategy to measure individual adaptability. To explore the individual determinants of these recognition and adaptation abilities, we collect a series of additional behavioral measures and correlate these individual characteristics to task performance. Ultimately, we find that individuals demonstrating greater numeracy perform best in changing inflationary conditions as well as respond best to our financial-education intervention, whereas subjects with the most inconsistent economic preferences perform significantly worse on both counts.

[1] This chapter is based off Lawrence, N., Guille, M., & Vergnaud, J.-C. (n.d.). *Inflation and Behavior: An Experimental Analysis* (LEMMA Working Paper) [Working Paper]. Université Paris-Panthéon-Assas, LEMMA.

1. INTRODUCTION

For over three decades (the 1990s to 2020s), developed economies enjoyed low and stable inflation. This historically unusual calm was abruptly shaken by a series of economic headwinds. Beginning in 2020, the onset of the COVID-19 pandemic segued into the first significant rise in inflation in at least a generation one year later. Subsequently, the Russia-Ukraine conflict further accelerated inflation. Given the extended period of low inflation experienced in developed countries, it is likely that individuals have struggled to anticipate, or even perceive, its sudden rise and to effectively adjust their consumption and saving decisions to mitigate its impact. For the same reasons, the analysis of how agents form their perceptions and expectations and adapt their behavior in response to inflation, especially at the individual level, has long been neglected, despite the important role of inflation perceptions and expectations in macroeconomic models and for the ability of central banks to reach their objective of price stability (Abildgren & Kuchler, 2021; Weber, Gorodnichenko, et al., 2023).

Indeed, some of the numerous, mainly macroeconomic, studies on inflation dating back to the 1970s—a period marked by a significant surge in inflation in many developed economies—had already highlighted pronounced shifts in households' savings and consumption behaviors as a function not only of the inflation rate they faced, but of the rate they anticipated facing. In particular, increases in the rates of households' expected inflation correlated with increases in nondurable goods consumption, or "stocking up." Decreases in anticipated inflation similarly correlated with increased savings rates (Juster & Wachtel, 1972; Katona, 1974). In other words, when households expected a rise in prices, they would naturally make purchases in advance to avoid paying at higher prices later; conversely, when they did not anticipate price increases, they would rather save money.

This dichotomous correlation between households' inflation expectations and savings-consumption decisions was for instance observed in the United States, when in addition to the headline geopolitical tumult, the infamously long lines at gas stations of the 1979

Oil Crisis distinctly correlated with high levels of expected inflation (*Expected Change in Prices during the next Year*, 2023; Verleger, 1979). Similarly, the United States saw an increase in the personal savings rate at the same time as a drop in the expected inflation rate (*Expected Change in Prices during the next Year*, 2023; U.S. Bureau of Economic Analysis, 2024d).

On the other hand, there is equally substantial evidence that individuals do not make appropriate decisions when faced with inflation. Households typically demonstrate quite inaccurate estimations of inflation. In particular, a broad range of survey-based evidence indicates that households' inflation perceptions persistently exceed the inflation level measured by official consumer prices indices and their expectations are subject to similar biases, as shown by Jungermann et al., (2007), Abildgren & Kuchler (2021), and Cornand & Hubert (2022).

Such biases can confound households' decision-making. One can logically expect that over-anticipating inflation will lead to over-consumption, while under-anticipating will lead to under-protecting wealth and income from losses in real value. Moreover, Katona (1974) postulated at the time that when consumers underestimated future inflation, they would fail to recognize the role inflation was playing on their subsequently worsening financial state. Consumers misinterpreted their increasing financial hardship as being simply the result of a "bad economy" or poor personal financial management and, thus, believed they needed to save more and/or act in a more financially responsible manner—as opposed to limiting exposure to losses in real value.

During the 1970s and 1980s in developed economies, these mistakes were commonplace. While households would increase savings in anticipation of a decrease in inflation, they regularly under-anticipated and ultimately saved at negative real interest rates (*Expected Change in Prices during the next Year*, 2023; Stephens & Tyran, 2017; U.S. Bureau of Economic Analysis, 2024d).

As a result, central bankers have long focused on managing expectations of inflation as a means of maintaining stable consumer behavior and, ultimately, prices (Bernanke, 2007). Given the importance monetary policy assigns to anchoring household inflation expectations, the contemporary literature has thus focused primarily on perceptions and expectations of inflation at a macroeconomic scale.

But, while one should theoretically exist, the contemporary research has not yet identified a clear connection between perceived and expected inflation and the resulting economic behavior (Gautier & Montornès, 2022). At first glance, these behavioral patterns seem both natural and reasonable; however, their ultimate economic effectiveness depends on households' ability to accurately anticipate and perceive inflation. Thus, two foundational questions remain unanswered: do individuals make appropriate decisions when faced with inflation, and is an individual's adaptability to inflation related to their perceptions and expectations of inflation?

There is almost no micro-level data on individuals' decision-making when faced with inflation because the range of data required to assess one's adaptability is too wide for large-scale collection. A few notable exceptions, however, do exist of laboratory (Georganas et al., 2014; Kawashima, 2006) and natural (Jungermann et al., 2007) experiments. Kawashima (2006) who finds inflation increases subjects' delay discounting in a laboratory-based intertemporal consumption task. Jungermann et al. (2007) show that the availability heuristic and loss aversion lead to overestimations of perceived inflation, while Georganas et al. (2014) provides further evidence that the availability heuristic distorts individuals' perceptions of inflation.

Nevertheless, the large majority of research is macroeconomic, relying on survey data to measures households' perceptions and expectations. In theory, better perceptions and expectations should correlate positively with adaptability; however, the lack of micro-level behavioral data makes establishing the relationship between perceptions and expectations of inflation and individuals' behaviors more difficult. Experimental economics, however, offers an efficient way to study this relationship at the individual level. Therefore, we develop a novel, controlled experiment that measures individuals' adaptability to and perceptions and expectations of inflation. We expect to observe that many subjects do not adapt effectively to inflation, that there is significant heterogeneity across subjects, and that subjects' inflation perceptions and expectations influence how they adjust their decisions when faced with rising prices.

What contemporary macro-level research has revealed is that households demonstrate quite inaccurate perceptions and expectations of inflation. These issues can not only complicate monetary policy transmission, but lead household decision-making astray (Abildgren & Kuchler, 2021). Perceived and expected inflation have consistently exceeded measured inflation rates, and both have varied widely and consistently across certain demographic and cognitive factors (D'Acunto et al., 2022). Women, the poor, the less-educated, and those with lower IQs demonstrate greater estimation biases. Those who have previously experienced high-inflation periods typically produce higher estimates (Bruine de Bruin et al., 2010; D'Acunto et al., 2022).

How these perception and expectation biases ultimately affect behavior, however, remains unclear. At the macro-level Burke and Ozdagli (2021) find little impact on consumption behavior in the United States, whereas Dräger and Nghiem (2021), Ichiue and Nishiguchi (2015), and Andrade et al. (2023) find positive relationships in Germany, Japan, and France respectively between the inflation rate households expect and their consumption. Therefore, we additionally expect that individual characteristics related to divergent inflation perceptions and expectations—particularly cognitive abilities, loss and risk aversion, and delay discounting—correlate with an individual's adaptability to inflation as well. To address this question, we measure subjects' characteristics and cognitive and economic capacities, correlating them with their performance, perceptions, and expectations in our experimental inflation task.

Further, although there is little research into how inflation affects people's behavior at the individual level, there exists a sizable literature that finds that financial literacy and numeracy as well as a number of economic preferences correlate positively with financial behavior (Darriet et al., 2020; Lusardi & Mitchell, 2014; Nieddu & Pandolfi, 2021). As such, we further anticipate that a financial education intervention can improve individuals' decision-making and adaptability to inflation.

To measure individuals' adaptability to inflation, we design a novel intertemporal consumption-savings experimental task that allows us to control the inflationary conditions and observe subsequent behavioral changes as inflation changes. We apply this task in a scalable online experiment to test the following hypotheses:

1. subjects do not perform well in the inflation task, and less accurate perceptions and expectations of inflation correlate to a lower performance in the task and, thus, less adaptability to inflation,
2. heterogeneity of behavior in the experimental task can be explained by differences in individual characteristics, and
3. subjects are capable of improving their behavior through learning and a financial-education intervention.

Overall, we find that subjects perform well below the benchmark performance and that the less accurate a subject's perceptions and expectations of inflation, the worse they perform as well. Compared to real-life behavior, subjects demonstrate similar in-task perception and expectation inaccuracies. Surprisingly, whereas in phases of low inflation, subjects demonstrate the standard inflation overestimation biases (Abildgren & Kuchler, 2021), during phases of high inflation, they demonstrate exponential growth bias (Schonger & Sele, 2021; Stango & Zinman, 2008) and underestimate inflation instead. Across subjects, we observe significant performance heterogeneity and find statistically significant positive correlations between their numeracy and performance as well as negative correlations between their degree of inconsistency in economic preferences and performance. Finally, we find that subjects improve their performance over repeated sessions of the task (a "learning effect"); subjects with greater mathematical abilities and greater adaptability improve their performance further after receiving the financial-education intervention, while other subjects do not improve performance with the intervention.

In the sections that follow, we present our experimental task and protocol (Section 2), the results (Section 3), and a discussion of the implications for our three hypotheses and for future research (Section 4).

2. METHOD

The experiment takes place online over the course of four days for each subject and comprises our primary inflation-behavior task (the "Savings Game") and a battery of supplemental questionnaires and behavioral tasks. We first present the Savings Game (Section 2.1) and our method for analyzing behavior in the game. Then, we present the experiment's procedural implementation (Section 2.2) and the battery of additional questionnaires and tasks (section 2.3).

2.1. Savings Game

We design the Savings Game so that we can measure subjects' adaptability to inflation. When faced with inflation, a rational economic agent should make savings and consumption decisions so as to maximize their purchasing power—even if empirical evidence shows this is not always the case (Bourgeois-Gironde & Guille, 2011). In particular, at the individual level, surveys and experiments show that many individuals fail to correctly take inflation into account when making financial decisions, demonstrating money illusion (Darriet et al., 2020; Shafir et al., 1997).

The objective is to expose individuals to various price changes in order to simultaneously measure how they perceive and anticipate inflation based solely on prices and how they adjust their decisions accordingly.

To this end, the Savings Game presents an intertemporal savings and consumption task, where the optimal decision varies between saving and purchasing depending on inflation. We maintain the nominal interest rate fixed, so optimal decision-making is in fact a function of the real interest rate.

2.1.1. Main rules

Subjects are remunerated based on the balance in their interest-earning experimental savings account at the end of each round of the game. We define a game round to span

120 periods (presented to subjects as "months"), during each of which subjects must decide between saving money or making purchases of the experimental good, one unit of which they must consume each period to survive.

Over the 120 periods, prices increase at varying rates, while the nominal interest rate remains constant, producing phases of positive or negative real interest rates. Whereas experiments using intertemporal consumption tasks remunerate via consumption (Brown et al., 2009; Kawashima, 2006), the Savings Game treats consumption as a condition, which subjects must meet to proceed through and ultimately finish a given round. This approach aims to both incentivize subjects to pay attention to the real interest rate as well as more closely replicate real-life purchase decision-making processes, where saving money itself can bring utility.

Subjects start in period $t = 1$ with a savings account holding an initial endowment, w, and receive an additional period income of y. These funds can be used to purchase units of the experimental good (presented to subjects as "food") at the unit price p_1. Unspent funds remaining in the savings account and accrue interest at a constant nominal rate r per period. From period $t = 2$ onward, subjects have savings equal to the capitalized savings plus the per-period income y.

Each period, subjects decide the quantity q_t of the good to purchase, ensuring they have at least one unit of the good in their stock ($B_t \geq 1$), for utilization in the period. The good is nonperishable, and subjects can stock as much as they like. If at any point, they end a period with $B_t < 1$, they cannot survive to the next period. At this point, the round of the game ends immediately, and their savings account balance is recorded as 0, meaning they receive no remuneration for the failed round.

The unit price p_t of the good can change each period. It can only increase with a positive inflation rate π_t , such that $p_t = p_{t-1}(1 + \pi_t)$. The inflation rate π_t is exogenously determined and can be inferior or superior to the nominal rate r. Subjects are informed that prices can change but only increase so that we can ensure their decisions are never influenced by an expectation of deflation.

To sum up, the Savings Game can be described by the following steps:

1. At $t = 1$, the subject begins with an initial endowment, $S_1 = w + y$.
2. The total funds available at the beginning of any given period is $S_t^o = S_{t-1}^f(1 + r) + y$.
3. The total spent for any given period is $p_t q_t$ and the stock of the good is $B_t = B_{t-1} - 1 + q_t$.
4. The end of period savings balance is $S_t^f = S_{t-1}^f(1 + r) + y - p_t q_t$.
5. The subject's final gain equals their savings account balance at $t = 120$. Any remaining potential stock of goods is lost.

The challenge of the game lies in balancing the need to maximize savings with the potential to stock up on goods before the price increases. It is advantageous to save when the real interest rate is positive and to stockpile as soon as the real interest rate becomes negative.

Prior to playing the first round of the Savings Game, subjects receive detailed instructions on the game's rules as well as how to operate the game's interface (for a detailed explanation, see Appendix A.2. Savings Game instructions). They are informed about the game's objective and their remuneration, how savings are accumulated, the need to finish each period with a minimum stock of $B_t = 1$, the constancy of the nominal interest rate and endowment per period, and the possibility that prices can increase (but not decrease) each period. They must also correctly answer comprehension questions during the instructions prior to starting the first session. We do not provide further information regarding inflation and the real interest rate so that we can estimate if and when subjects recognize the change in inflationary conditions and real interest rate. This approach is based on Behrens et al. (2007), who measure individuals' adaptability to changing environments through a one-armed bandit task, whereby over time, the probability of an option being the correct choice switches on a regular basis. We apply this same process of changing environment, where inflation is the environmental variable we control.

2.1.2. Experimental parameters

Figure 1 shows the Savings Game's user interface through which subjects receive information and make choices for each period. The Savings Game interface is developed using oTree, an open-source software development framework built on Python and Django (Chen et al., 2016); the codebase is freely available for use at https://github.com/o-nate/savings-game (Lawrence, 2024b).

We utilize the "₮" symbol as our experimental currency unit to align monetary values with the format encountered in subjects' daily lives, while also avoiding a generally recognizable currency symbol for within our subject population.

The parameters are as follows:

- initial endowment, w, of ₮863.81,
- per-period income, y, of ₮4.32,
- savings account interest rate, r, 1.9% per period,
- initial price of the good, p_1, ₮8.07.

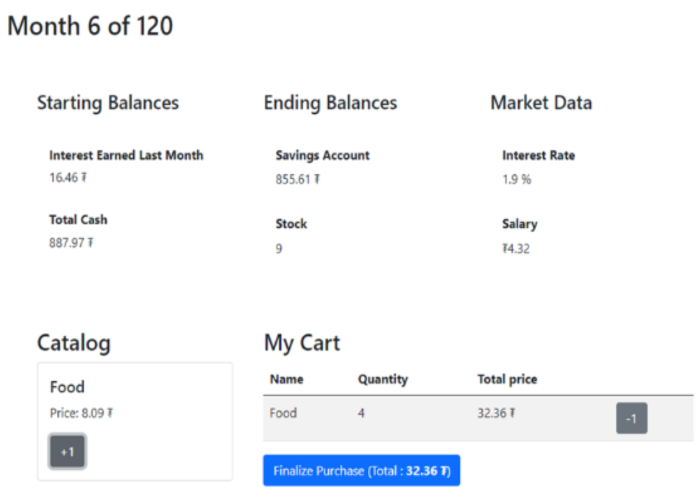

Figure 1 - Savings Game user interface

On the screen, the total interest earned in the previous period and total cash available are displayed in Starting Balances. Additionally, given the currently selected quantity and current price, the amount to be saved for the next period and current stock of the good are automatically calculated for the subject and displayed in Ending Balances. The total to be spent, given the current selection in My Cart is displayed on the Finalize Purchase button. Once satisfied with their selected quantity, the subjects finalize their purchase and proceed to the following period by clicking Finalize Purchase. If at any time, a subject ends a period with a stock balance, $B_t < 1$, a pop-up message appears on the screen warning them that if they continue, they will not survive to the next period, recommending they review their decision. If the subject does not have enough Total Cash to purchase any units of the good, they must then confirm they understand that the Savings Game round will end.

There are two possible inflation sequences. Over the course of four Savings Game rounds, subjects engage in each inflation sequence twice. One has four inflationary phases of 30 consecutive periods each ("4x30"), with two phases of high inflation (negative real interest rate) and two of low inflation (positive real interest rate). The other sequence has ten inflationary phases of 12 consecutive periods each ("10x12"), with five phases of high inflation (negative real interest rate) and five of low inflation (positive real interest rate). Figure 2 demonstrates the price evolution of one unit of the good in each sequence. This approach, using sequences of different inflation and thus real interest rate phases, is based on Behrens et al. (2007). As mentioned above, in the Behrens et al. (2007) experiment, the probability of an option being the correct choice switches on a regular basis—the result of changing environmental conditions. Similarly, the correct choice in the Savings Game changes between saving and buying with each change in inflation phase—the environmental variable we control. This approach allows us to compare subjects' adaptability to a changing environment that requires changing strategy.

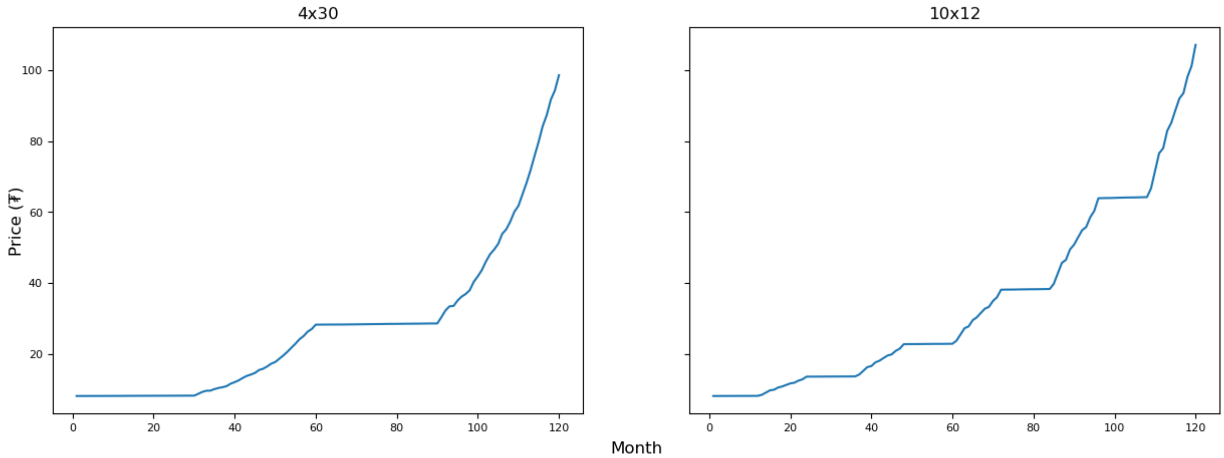

Figure 2 - Price evolution of inflation sequences

During low-inflation phases, the average per-period inflation rate is approximately 0.04%, exhibiting very low variability (between 0% and 0.08%). In high-inflation phases, the average per-period inflation rate is around 4.2% for the 4x30 sequence and 4.4% for the 10x12 sequence, with higher variability (ranging between 0.3% and 6.3% for 4x30, and between 1.6% and 7.4% for 10x12).

The experimental parameters are configured to create an environment where adopting a "naïve" strategy of simply purchasing one unit of the good per period, allows survival but produces a final savings balance well below the maximum possible. Indeed, the inflationary conditions were defined such that purchasing no more than one unit in a given period ("saving") is only appropriate in low-inflation phases, producing high opportunity costs during high inflation. In both sequences, the maximum-performance ("best") strategy involves saving during the initial low inflation phase and, at the onset of the first high-inflation phase, acquiring all units of the good necessary to survive the remaining periods in a single transaction ("stocking up"). The best strategy yields for the 4x30 and 10x12 sequences ₮4119.38 and ₮2420.59, respectively, a naïve strategy yields only ₮2,261.29 and ₮276.55, respectively.

Given the lack of information subjects receive about the future price of the good, the best strategy is not something we expect subjects to achieve, at least the first time they play the game. As such, we anticipate that subjects' performance should fall somewhere between the naïve and the best strategies' performances. Our primary outcome measure, therefore, is the final balance in subjects' savings account.

2.1.3. Intervention

Before the start of the third round of the Savings Game, half of subjects are randomly selected to receive a simple financial education intervention.[2] The financial education provides short textual explanations of inflation and interest and how they both relate to purchasing power (See Appendix A.3. Intervention for the complete intervention). Subjects are told that in order to maximize their savings, they must protect their purchasing power. Doing so means they must save when the inflation rate is less than the interest rate and, as soon as the inflation becomes greater than the interest rate, they must stock up. In other words, they should save money as long as $r > \pi_t$ and stock up as soon as $r < \pi_t$.

After reading the brief texts, subjects must then answer some comprehension questions in which they are shown screens from the Savings Game as well as given contextual information and must determine the status of their purchasing power and what they should do in the situation. See Appendix A.3. Intervention for the complete treatment provided.

2.1.4. Performance and adaptation to changing inflation phases

Our baseline performance measure is subjects' savings balance at the end of the 120 periods. Subjects' abilities to protect their purchasing power and adapt to changes between low- and high-inflation phases determine how much they can ultimately save. As such, subjects' inability to protect purchasing power and adapt produce opportunity costs that result in lower final savings. These opportunity costs arise from three

[2] For hands-on demo of the intervention, visit https://savingsgame.org/demo/intervention.

possible mistakes: stocking too much ("wasteful-stocking"), stocking in low inflation ("over-stocking"), and saving in high inflation ("under-stocking").

The maximum achievable balance, produced by the best strategy for each inflation sequence, provides a benchmark. We can then directly calculate the opportunity cost of each error by decomposing a subject's divergence from the benchmark best strategy's result, as described below.

The most obvious mistake is buying more of the good than necessary. *Wasteful-stocking* occurs when a subject purchases more units of the good than required to survive the 120 periods, such that $B_{120} > 1$. Figure 3 provides an example in which a hypothetical subject purchases nine units of the good in excess in the 4x30 inflation sequence. The wasteful-stock becomes apparent as the blue bars surpassing the "best" strategy's stock, represented by the orange bars at period $t = 98$. When a subject purchases excess units, they forfeit the savings corresponding to the additional purchases and the potential interest they could have accrued on that savings. Calculating the opportunity cost for wasteful-stocking involves determining what the total gain would have been if these unnecessary purchases had been avoided. Figure 4 demonstrates the impact on the stock and savings of eliminating these superfluous purchases. Whereas the original final savings balance was ₮1778.43, by eliminating the excess purchases, the final savings now increase to ₮2487.70. This difference between the real and hypothetical performance with no excess purchases indicates ₮709.27 of wasteful-stocking cost.

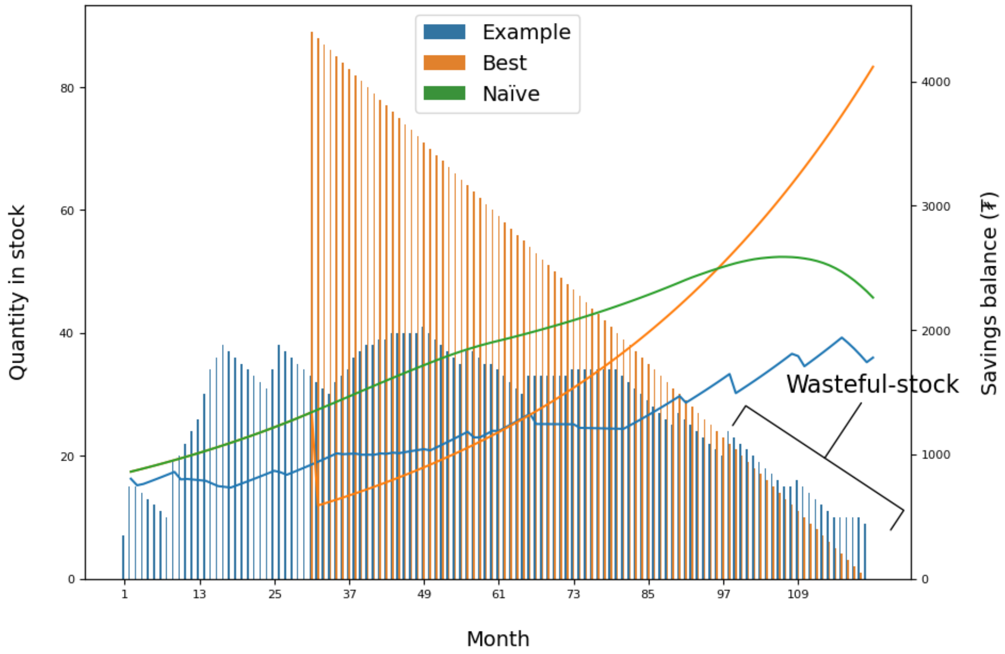

Figure 3 - Example subject performance compared to best strategy in the 4x30 sequence

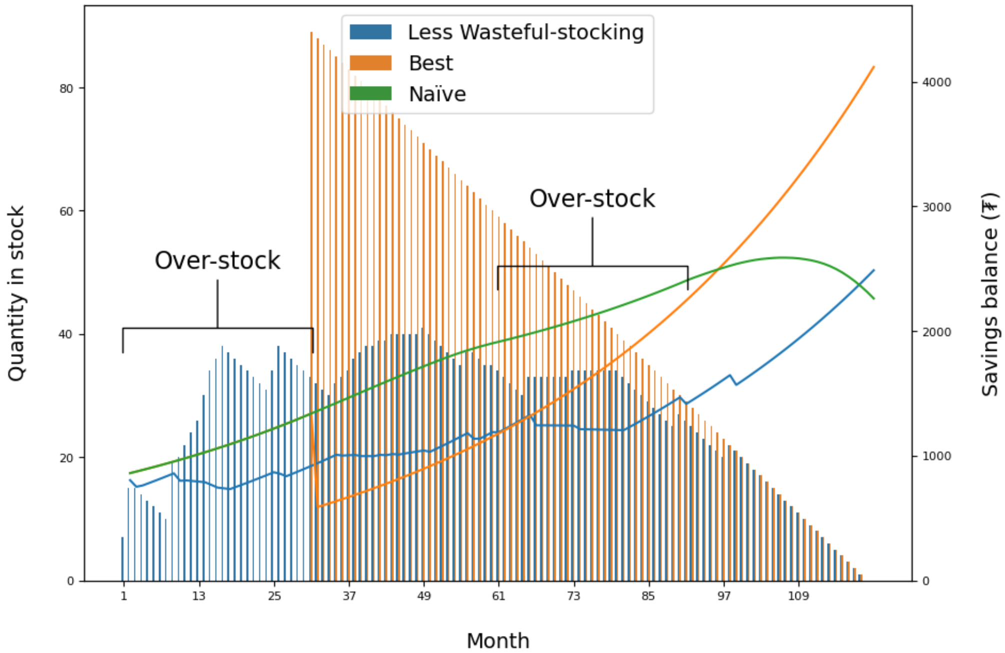

Figure 4 - Example subject performance with wasteful-stocking removed

The second mistake, *over-stocking* occurs during periods of low inflation, when the real interest rate is positive. During low inflation, the interest earned on savings accrues more quickly than the price of the good increases, meaning that purchasing more than the one unit per period necessary to survive incurs an opportunity cost of foregone interest income. The hypothetical subject in Figure 3 and Figure 4 demonstrates over-stocking, amassing a stock in the first low-inflation phase, prior to period $t = 31$, rather than purchasing only one unit of the good per period. As a result, they sacrifice the interest that could have been accrued on the money otherwise spent too soon. The same applies to the second phase of low inflation, during periods $61 \leq t \leq 90$, when the subject makes additional purchases despite having sufficient stock to survive the low-inflation phase while accruing interest on the money they spend. The unnecessary purchases made during this second phase of low inflation would have been preferable to postpone until period $t = 91$. We can calculate the opportunity cost of over-stocking by determining what their total gain would have been had they deferred additional purchases during the phases of low inflation until the start of the subsequent high-inflation phase. Figure 5 shows how eliminating this over-stocking affects stock and savings. Without the over-stocking, the final savings increases to ₮3536.24, implying a corresponding opportunity cost of ₮1048.54.

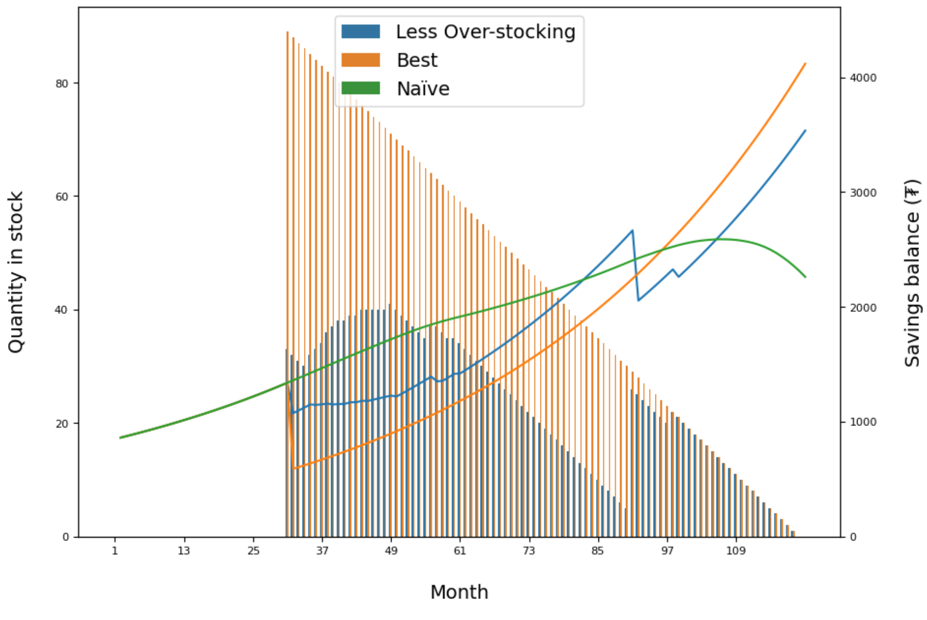

Figure 5 - Example subject performance with wasteful- and over-stocking removed

The third mistake, *under-stocking*, relates to insufficient stocking at the beginning of high-inflation phases. This error incurs a cost as subjects ultimately pay a much higher price for the good. The opportunity cost of under-stocking is the difference between the interest that could have been earned on the money saved by purchasing at a lower price and the additional interest earned by saving for a longer period. We can calculate the associated opportunity cost by determining what the final savings would have been had the subject appropriately stocked up at the onset of high inflation by calculating the difference between the sequence's maximum savings and the subject's savings adjusted to remove wasteful- and over-stocking. For the hypothetical subject in Figure 5, the difference between the maximum of ₮4119.38 and adjusted final savings of ₮3536.24 is ₮583.14, which is the under-stocking opportunity cost.

For further information, see Appendix A.4. Opportunity cost calculation for further discussion on the opportunity cost calculations.

Finally, as can be seen in the Figure 3, Figure 4, and Figure 5, the best strategy requires stocking up a large amount at the onset of inflation (108 units at $t = 13$ in sequence 10x12 and 90 units at $t = 31$). This requires subjects quickly and significantly adapt their purchase behavior to avoid future under-stocking costs. We can measure subjects' immediate purchase adaptation to changes in inflation phases by calculating the difference between the quantity purchased on average in the first 3 periods of high inflation and that purchased in the last 3 periods of the preceding low-inflation phase. As a benchmark, the best strategy requires purchase adaptations of 29 and 35 units in 4x30 and 10x12 respectively.

2.1.5. Measures of perception and expectation of inflation

Every twelve periods in the Savings Game, we measure subjects' perceived inflation rate for the preceding twelve periods and expected inflation rate for the next twelve periods. Both measures are elicited through a *slider*, horizontal percentage scale ranging from -100 % to + 100 % in 1% increments as shown in Appendix A Figure 4 in Appendix A.5. Additional in-task measures.

From these two measures, we construct bias and sensitivity indicators. Perception and expectation bias are the difference between actual (past and future inflation) and subjective values (perceived and expected).

Perception bias is $P_{bias}(\pi_t, \pi_t^p) = \pi_t - \pi_t^p$, and expectation bias is $E_{bias}(\pi_{t+1}, \pi_t^e) = \pi_{t+1} - \pi_t^e$, where π_t^p and π_t^e are subjects' reported perception and expectation of inflation at period t (for the corresponding 12 periods before or after respectively).

We calculate global values for each indicator as well as values for bias in the high- and low-inflation phases specifically.

Perception and expectation sensitivity are the Pearson correlations between actual (past and future inflation) and subjective values (perceived and expected).

A positive (negative) bias implies an overestimation (underestimation). The larger a bias's magnitude, the greater the divergence in estimation from the actual inflation rate. A positive (negative) sensitivity means that a subject correctly (incorrectly) adjusted their estimations in the same direction as changes in actual inflation. The closer the sensitivity to 1, the more accurately a subject adjusted their perception or expectation. Sensitivity near 0 suggests a subject did not adjust their perception or expectation at all, while sensitivity near -1 suggests a subject adjusted their perception or expectation converse to the changes in actual inflation.

We take additional perception measures during the task that were not included in the final analysis for this paper. See Appendix A.5. Additional in-task measures for further information.

2.2. Experimental procedure

We pre-register the experiment on AsPredicted and conduct it online in French using the hosting services of the S2CH Research Federation. We recruit subjects from the volunteer pool of the Laboratory of Experimental Economics in Paris (LEEP) through an online system (ORSEE).

The experiment lasts four days. Figure 6 depicts the procedure over the course of these four days. Each day, subjects receive an email with a unique URL link to the experiment's session, which they must complete on a computer (we block access from mobile phones and tablets). On average, subjects spend between 15 and 30 minutes on the experiment each day; however, there is no time limit.

Subjects complete the two inflation sequences (4x30 and 10x12) in randomized order during days 1 and 2 and again on days 3 and 4, again in randomized order. The battery of additional tests includes knowledge questionnaires and economic preference tasks. Knowledge questionnaires include specific questionnaires to measure subjects' financial literacy, inflation awareness, and numeracy. Economic preference tasks include a risky choice lottery and bomb risk elicitation task (BRET) to measure risk preferences, risky choice lottery with loss to measure loss aversion, Wisconsin card sorting task (WCST) to measure adaptability, and smaller-sooner/larger-later binary choice task to measure time preferences. We describe the tests in further detail below and in Appendix A.6. Knowledge measure questionnaires and Appendix A.7. Economic preference tasks. Subjects are additionally remunerated based on the results they achieve in the economic preference tasks, except for the binary choice task.

Subjects receive payment in euro upon completing all four days' tasks and questionnaires. The final gain is the sum of nine components: the sum of the four Savings Games' gain in euros, with an exchange rate of ₮750 = €1; the outcomes of the risk aversion lottery, loss aversion lottery, BRET, and Wisconsin card sorting task; and a €12 participation fee. The maximum final savings possible over four rounds of the Savings Game is ₮13,080.46 (€17.44), and the maximum final remuneration, including participation fee and additional tests, is ₮33,817.50 (€45.09).

Day 1 begins with initial instructions on the overall experimental procedure and a demographics questionnaire.[3] Then, subjects receive instructions on the Savings Game

[3] For a hands-on demo of the Savings Game instructions, visit https://savingsgame.org/demo/instructions.

and play their first round. Afterwards, they complete one of the economic preference tasks, which is randomly assigned.

Subjects begin day 2 with one of the randomly assigned knowledge questionnaires. They then play the second round of the Savings Game and complete the remaining two knowledge questionnaires in random order.

When subjects enter the session on day 3, the half of subjects randomly assigned to the treatment group receive the financial education intervention, and the control group is simply shown a screen informing them that the next round of the Savings Game will now begin. They then complete the third round of the Savings Game. Next, they complete the remaining economic preference tasks in randomized order.

Finally, day 4 follows the same procedure as day 2. Subjects begin with one of the randomly assigned knowledge questionnaires. Next, they play the fourth and final round of the Savings Game and complete the remaining two knowledge questionnaires in random order. Afterwards, they are shown a summary of their performance in the four rounds as well as remunerated economic preference tasks and informed of their total remuneration. From there, they are redirected to a separate web portal to receive payment.

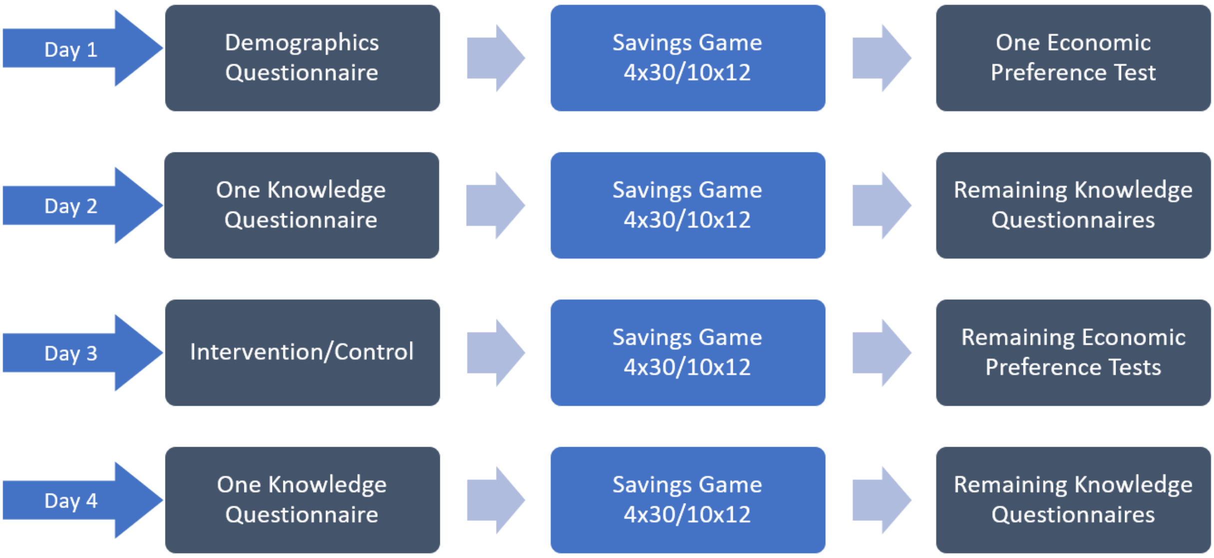

Figure 6 - Experimental design. Economic preference tests include time preferences, risk preferences (Holt & Laury, BRET), loss aversion, and Wisconsin card sorting task. Knowledge questionnaires include financial literacy, numeracy, and inflation

2.3. Questionnaires and other tasks

2.3.1. Demographics

The initial demographics questionnaire elicits subjects' demographic and socioeconomic information. This includes gender, age, education level, employment status, income, savings, and debt.

2.3.2. Knowledge

There are three knowledge questionnaires: financial literacy, inflation awareness, and numeracy.

The financial literacy questionnaire includes the "Big Three" questions from Lusardi and Mitchell (2009) as well as an investment product risk categorization from Arrondel and Masson (2014). A subject's financial literacy is determined by their correctly responding to the "Big Three" questions from Lusardi and Mitchell (2009). We also include a question on investment product risk categorization from Arrondel and Masson (2014). If a subject fails to answer correctly question 3 of the Big Three but correctly categorizes the investment products' risk, we consider them financially literate.

The inflation awareness questionnaire presents questions to assess subjects' knowledge of, ability to mathematically reason about, and real-life behavioral responses to inflation. Subjects provide multiple inflation estimates: the highest and lowest rates in France over the last 30 years, the current rate, and the rate they expected over the following 12 months (Macchia et al., 2018). They also answer questions that require compounding calculations (Macchia et al., 2018) or about their perceptions and expectations of changes in their purchasing power. Finally, they answer questions on how they would adjust various behaviors related to saving and spending if prices were to rise over the next 12 months. We use these responses to construct measures of their inflation perception, ability to conduct compounding calculations, and real-life adaptability to inflation.

The numeracy questionnaire consists of an adaptive version of the Berlin Numeracy Test (Cokely et al., 2012), which assesses subjects' probability reasoning. We use their responses to construct a numeracy measure.

See Appendix A.6. Knowledge measure questionnaires for further details.

2.3.3. Economic preference tasks

The economic preference tasks include:

- an intertemporal randomized choice sequence similar to Cohen et al. (2016) to measure time preferences;
- a Holt and Laury (2002) lottery choice procedure to elicit risk aversion;
- a bomb risk elicitation task (BRET) by Crosetto and Filippin (2013) to measure risk tolerance;
- a lottery choice task with loss to measure loss aversion, similar to Gächter, Johnson, and Herrmann (2022); and

- a Wisconsin card sorting task (WCST) to assess subjects' adaptability to changing environments (Axelrod et al., 1992; Leshem & Glicksohn, 2007).

Additionally, we develop a proxy measure for determining an the inconsistency of subjects' economic decisions (Kurtz-David et al., 2019) based on the number of times the subjects make conflicting decisions—the number of *switches*—during the economic preference tasks.

For further detail, see Appendix A.7. Economic preference tasks.

2.4. Hypotheses

As mentioned in above, our experiment aims to test the three hypotheses that:

1. subjects do not perform well in the inflation task, and less accurate perceptions and expectations of inflation correlate to a lower performance in the task and, thus, less adaptability to inflation,
2. heterogeneity of behavior in the experimental task can be explained by differences in individual characteristics, and
3. subjects are capable of improving their behavior through learning and a financial-education intervention.

In the following section, we analyze the results.

3. RESULTS

3.1. Descriptive statistics: Subjects

104 subjects complete the entire experiment with comprehensive data (51 females and 53 males). They are 34.7 years old on average, ranging from 18 to 60. For 67 subjects, their highest degree is a master's; for 21, a bachelor's degree; for 13, high school diploma; and for three, a PhD. 86 subjects are employed, and the monthly median

income is €2032. 88 subjects report being able to save money each month, with a median monthly savings of €600. 23 subjects report having taken out debt other than a mortgage in the past 12 months. Finally, we note that the median savings rate is 22%, which is roughly in-line with the average household savings rate in France since 2020 (*Taux d'épargne Des Ménages En 2022: Données Annuelles de 1950 à 2022*, 2023). We use the median, rather than mean, for income and savings since we had some anomalous outlier responses.

3.2. Overall performance

Table 1 displays the final savings across all four Savings Game sessions and the final remunerations paid to the 104 subjects. On average, subjects achieve an average of ₮5,933.48 (€7.91) in total final savings for the four Savings Game rounds and an average final total remuneration of ₮18,757.50 (€25.01), 45% and 55% of the maximum respectively.

Table 1 - Total remuneration and overall Savings Game performance

	Mean	**Standard deviation**	**Minimum**	**50%**	**Maximum**
Final remuneration (€)	25.01	3.97	14.66	25.17	37.21
Total final savings, 4 sessions (₮)	5933.48	2076.92	181.47	6269.54	11363.21

3.3. Behavior in the Savings Game

The evolution of subjects' average stock of goods and savings amount during the two inflation sequences (4x30 and 10x12) is presented in Figure 7. On average, during the first two Savings Game rounds, subjects exhibit behavior that deviates significantly from the best strategy, performing slightly better than the naïve strategy of buying one unit per period and not stocking any goods. Their average total final savings over the two sessions amount to 41.6% of the maximum achievable savings in contrast to 38.8%

for the naïve strategy. We immediately observe significant over-stocking (i.e. amassing stocking during phases of positive real interest rate) in the early phases and wasteful-stocking (i.e. purchasing more units of the good than necessary to survive the 120 periods) at the end compared to the best strategy. As described below, we can decompose and quantify these behaviors further.

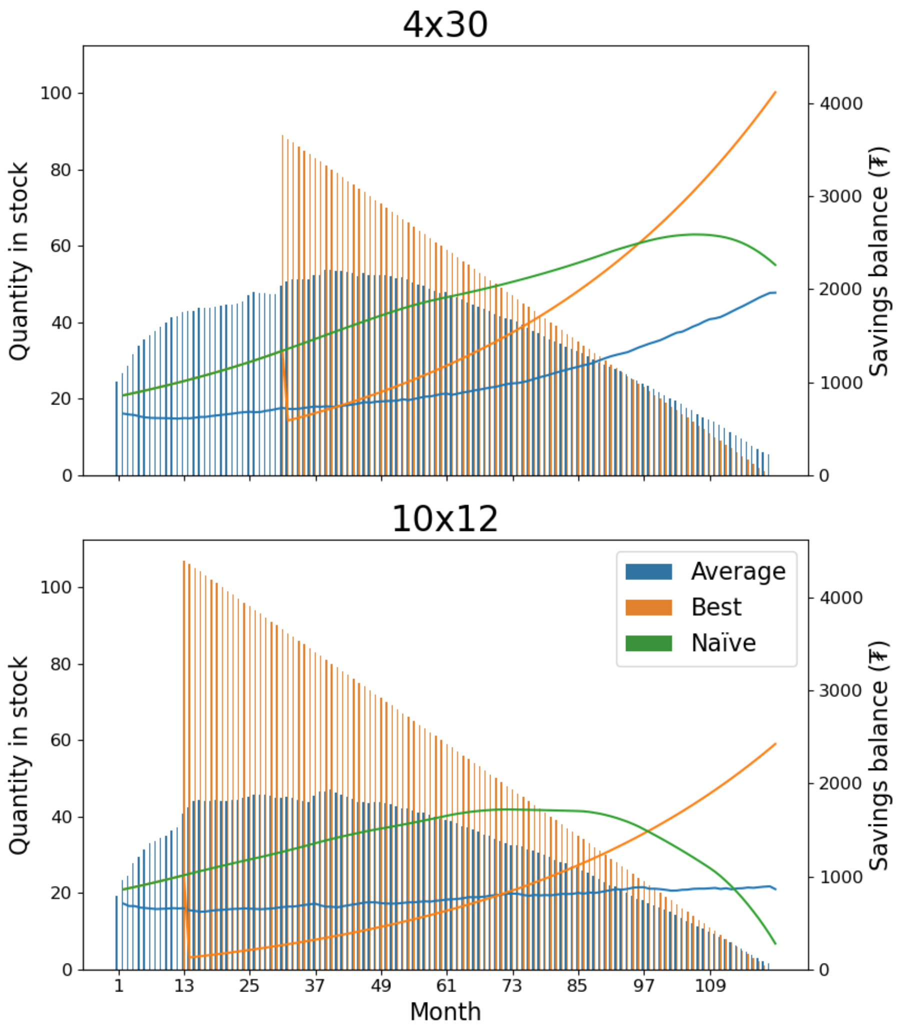

Figure 7 - Average stock of goods (vertical bars) and balance in savings account (lines) per period for subjects, for the best strategy, and for the naïve strategy for the first 4x30 and 10x12 inflation sequences

3.3.1. Performance and adaptation to changing inflation phases

Table 2 shows the average performance measures for both inflation sequences during the first two sessions. It should be noted that under-stocking as a performance measure is not entirely independent. Rather, the opportunity cost varies with the stock on-hand at the onset of a high-inflation phase. Indeed, the larger this stock, the less potential under-stocking opportunity cost the subject can incur. In other words, by definition, there is a negative correlation between over- and under-stocking costs. As a result, our analyses focus primarily on final savings and wasteful- and over-stocking opportunity costs as performance measures. Nevertheless, under-stocking is noteworthy conceptually since it reflects a failure to recognize a loss in purchasing power.

The opportunity costs associated with wasteful- and over-stocking explain much of the overall underperformance compared to the maximum savings via the best strategy. Over the two rounds, the over- and wasteful-stocking opportunity costs amount to the equivalents of 26.3% and 7.0% of the maximum possible savings respectively. In other words, subjects lost over a quarter of the maximum achievable savings to over-stocking opportunity costs.

The remaining opportunity cost arises from under-stocking, purchases made too late during periods of high inflation. At the onset of the first high-inflation phase (periods $t = 13$ and $t = 31$ for 10x12 and 4x30 respectively), the best strategy is to stock up the number of units necessary to survive until the end of the game. As seen in Figure 7, however, at the onset of the first high-inflation phase, the average stock increases but not sufficiently. Subjects insufficiently adapt to the change in the inflation phase.

We measure subjects' adaptation to changes in the inflation phase by calculating the difference between the quantity purchased on average in the first 3 periods of high inflation and that purchased in the last 3 periods of the preceding low-inflation phase. On average the purchase adaptation amounts to 1.38 and 1.29 units of goods for inflation sequences 4x30 and 10x12 respectively. In comparison, the best strategy requires purchase adaptations of 29 and 35 units in 4x30 and 10x12 respectively.

Further, comparing the two sequences in Table 2, we observe that subjects perform better overall in 4x30 than 10x12, achieving 48% of the maximum and 36% respectively. Indeed, this is not surprising since 10x12 presents a more difficult sequence since high inflation occurs earlier and more often, requiring subjects to adapt earlier and more often as well.

Subjects demonstrate a greater over-stocking loss in 4x30 than 10x12. In 4x30, subjects should buy one unit per period through period 30 and stock up at period 31, while for 10x12, they must buy one unit per period through period 12 and then stock up at period 13. As a result, the under-stocking loss is greater for 10x12 as shown in Table 2.

Finally, on average, the purchase adaptation amounts to 1.38 units in 4x30 ($p \leq 0.01$), a correct, yet nevertheless insufficient, increase in consumption (between periods $28 \leq t \leq 30$ and $31 \leq t \leq 33$). There is also an increase in consumption at $91 \leq t \leq 93$ ($p \leq 0.01$); although, in absolute magnitude, this adaptation is small given the relatively few remaining units required to survive through $t = 120$. In 10x12, the consumption change following the first increase in inflation (between periods $10 \leq t \leq 12$ and $13 \leq t \leq 15$) is positive but not significant. That said, the subsequent adaptation of 1.21 units at the second increase in inflation at $37 \leq t \leq 39$ is positive and statistically significant ($p \leq 0.01$). See Appendix A Table 1 in Appendix A.1. Additional results.

Nevertheless, there are clear correlations ($p \leq 0.01$) between the performance measures across both inflation sequences. See Appendix A Table 2 in Appendix A.1. Additional results. Purchase adaptation, and under- and wasteful-stocking cost measures correlate positively and significantly ($p \leq 0.01$) across sequences, suggesting that subjects demonstrate consistency in their mistakes across sequences.

Table 2 - Difference between performance measures of 4x30 and 10x12 sequences

	Final savings (%)	**Wasteful-stock (%)**	**Over-stock (%)**	**Under-stock (%)**	**Purchase adaptation**
4x30 mean	47.66	8.45	30.83	13.06	1.38
(std)	(20.99)	(17.15)	(23.52)	(13.16)	(4.13)
10x12 mean	35.56	5.51	21.83	37.10	1.29
(std)	(20.88)	(11.58)	(16.97)	(27.66)	(4.36)
Difference mean	12.10***	2.94*	9.00***	-24.04***	0.09
(std)	(27.18)	(14.83)	(28.45)	(25.91)	(5.32)
Total	41.61	6.98	26.33	25.08	1.33
(std)	(21.75)	(14.67)	(20.95)	(24.74)	(4.24)

Finally, we observe a strong heterogeneity in terms of performance in terms of the four measures of interest: total final savings, over- and wasteful-stocking costs, and purchase adaptation, as can be seen in Figure 8.

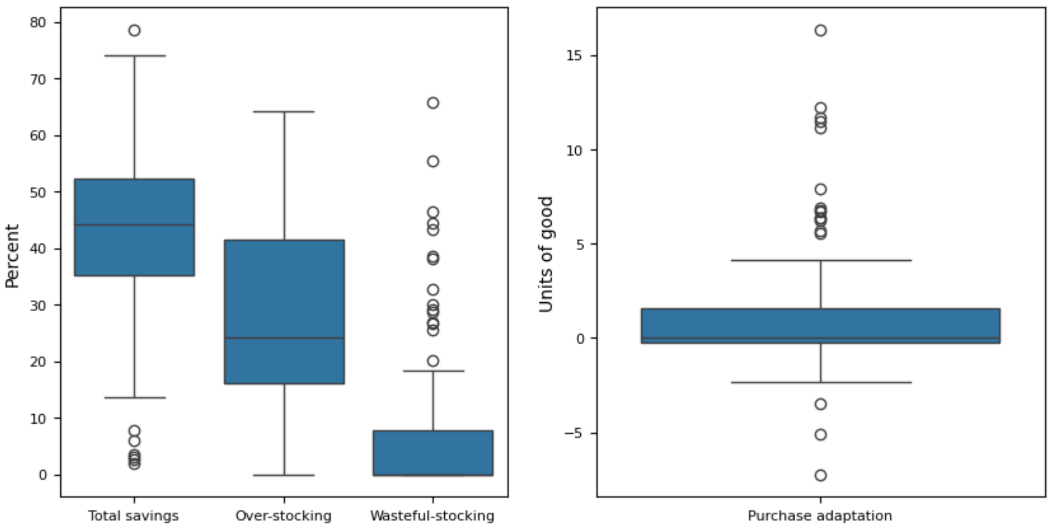

Figure 8 - Distribution of performance measures

3.3.2. Anticipation and perception of changing inflation phases

As shown in Figure 9, subjects have a reasonably good perception of inflation changes in both inflation sequences on average the first time they experience them. However, they tend to overestimate inflation on average when it is low, which is similar to patterns observed in macroeconomic data (Abildgren & Kuchler, 2021) and underestimate it when it is high, consistent with experimental results from Georganas et al. (2014) and exponential growth bias (Levy & Tasoff, 2016; Stango & Zinman, 2008). Being the case, subjects appear to not expect much disinflation generally.

Additionally, as seen in Figure 10, there are positive correlations between perceived and expected inflation, which is in-line with macroeconomic data on perceived and expected inflation in France as of 2022 (Bignon & Gautier, 2022). This is especially noteworthy for 10x12 since the correct correlation should be negative—when inflation is high, a subject should expect it to decrease. These results suggest that subjects form adaptive expectation, rather than the rational expectations normally assumed in the literature (Rocheteau, 2023).

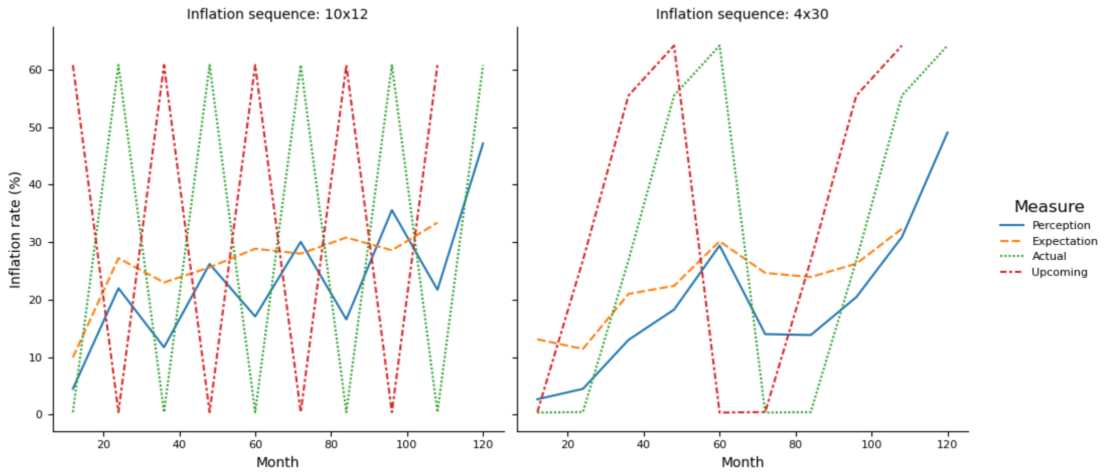

Figure 9 - Average inflation perception and expectation by sequence

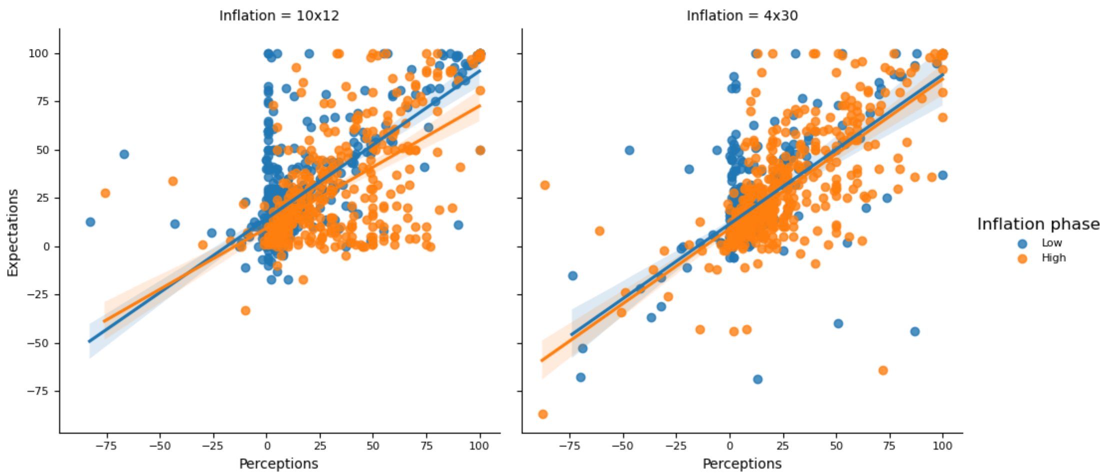

Figure 10 - Correlation between perceived and expected inflation

Table 3 shows the biases and sensitivities of perceived and expected inflation for each sequence. Subjects overestimate perception biases in low inflation (negative values) and underestimate in high inflation. Expectation biases in 4x30 tend to produce overestimations in low inflation and underestimations in high inflation, whereas in 10x12, subjects over-anticipate in high inflation (when inflation will soon decrease) and under-anticipate in low inflation (when inflation will soon increase). Perception sensitivities are positive for both sequences; however, expectations sensitivity is only positive for 4x30 and, nonetheless, close to zero for both sequences. Being the case, perceiving inflation is generally easier for subjects than anticipating it, considering the only information they receive is the price of the good and, in the instructions, that prices can increase but not decrease.

The results in Table 3 and Figure 10 for low-inflation phases of the two inflation sequences in rounds 1 and 2 are generally in-line with trends in real-life macroeconomic data from the European Union and France, where households' perceptions and expectations overestimate inflation (Abildgren & Kuchler, 2021; Gautier & Montornès, 2022). This macroeconomic data is primarily comparable to the low inflation phases in the Savings Game, considering the "high" in-task inflation is more than five times higher than the highest rate reached over the past 30 years in France as well as the on average within the European Union. Further, the positive correlation between perceptions and expectations is also similar to trends observed in macroeconomic data (Bignon & Gautier, 2022).

Table 4 shows the correlations between these measures across the two inflation sequences, allowing us to evaluate the consistency of subjects' biases and sensitivities across sequences as well. We see that expectations and perception biases show positive correlations ($p \leq 0.01$) between 10x12 and 4x30. Perception sensitivity also demonstrates positive correlations ($p \leq 0.01$) between sequences, but expectation sensitivity does not. This makes sense given the negative sensitivity subjects have in 10x12.

Table 3 - Perceived and expected inflation bias and sensitivity

	Expectation bias (High inflation)	Expectation bias (Low inflation)	Expectation sensitivity	Perception bias (High inflation)	Perception bias (Low inflation)	Perception sensitivity
4x30 mean	21.51	-4.63	0.12	21.99	-8.34	0.59
(std)	(22.62)	(19.86)	(0.31)	(20.47)	(13.85)	(0.29)
10x12 mean	-26.91	35.58	-0.09	28.59	-13.88	0.45
(std)	(23.59)	(21.05)	(0.38)	(22.00)	(18.85)	(0.34)
Difference mean	48.42***	-40.21***	0.21***	-6.6***	5.53***	0.14***
(std)	(20.91)	(20.31)	(0.53)	(20.05)	(17.99)	(0.29)
Total	21.51	-4.63	0.12	21.99	-8.34	0.59
	(22.62)	(19.86)	(0.31)	(20.47)	(13.85)	(0.29)

Table 4 - Correlations in biases and sensitivities across inflation sequences

	Expectation bias (10x12)	Expectation bias (4x30)	Expectation sensitivity (10x12)	Expectation sensitivity (4x30)	Perception bias (10x12)	Perception bias (4x30)	Perception sensitivity (10x12)	Perception sensitivity (4x30)
Expectation bias (10x12)	—							
Expectation bias (4x30)	0.6***	—						
Expectation sensitivity (10x12)	-0.09	-0.05	—					
Expectation sensitivity (4x30)	0.01	-0.07	-0.15	—				
Perception bias (10x12)	0.86***	0.48***	-0.1	0.05	—			
Perception bias (4x30)	0.44***	0.8***	-0.08	0.01	0.5***	—		
Perception sensitivity (10x12)	-0.22**	-0.08	-0.02	-0.09	-0.1	0.05	—	
Perception sensitivity (4x30)	-0.02	0.06	0.06	0.11	0.05	0.1	0.58***	—

3.3.3. Quality of inflation expectations and perceptions and performance

Table 5 exhibits correlations between inflation perceptions and expectations along with performance measures. Expected inflation sensitivity correlates positively and negatively by 0.208 ($p \leq 0.01$) and 0.344 ($p \leq 0.01$) with expectation biases in low- and high-inflation phases respectively. Perceived and expected inflation sensitivities also correlate positively with final savings by 0.201 ($p \leq 0.01$) and 0.139 ($p \leq 0.01$)

respectively. Perception sensitivity correlates positively, albeit weakly, with purchase adaptation by 0.067 ($p \leq 0.01$); however, there is no statistically significant correlation between expectation sensitivity and consumption change. This suggests that subjects who perceive and/or anticipate inflation more accurately perform better in the Savings Game.

These results, therefore, support Hypothesis 1 that subjects do not perform well in the inflation task and that less accurate perceptions and expectations of inflation correlate to a lower performance in the task and, thus, less adaptability to inflation.

We also note that perception bias in low-inflation phases correlates negatively with performance ($p \leq 0.01$), meaning that overestimating inflation correlates with lower performance. Conversely, expectation bias in low-inflation phases correlates positively with performance ($p \leq 0.01$), meaning that performance improves with a tendency to over-anticipate inflation in low inflation. In high-inflation phase, though, expectation bias correlates negatively with performance ($p \leq 0.01$), meaning that performance improves with a tendency to under- rather than over-anticipate inflation. These correlations make sense, considering that performance relies on subjects' abilities to anticipate and perceive the changes between low- and high-inflation phases.

Table 5 - Correlations between biases, sensitivities, and task performance measures

	Perception sensitivity	Perception bias (Low inflation)	Perception bias (High inflation)	Expectation sensitivity	Expectation bias (Low inflation)	Expectation bias (High inflation)	Purchase adaptation	Final savings
Perception sensitivity	—							
Perception bias (Low inflation)	-0.455***	—						
Perception bias (High inflation)	0.275***	0.582***	—					
Expectation sensitivity	0.065***	-0.172***	0.024	—				
Expectation bias (Low inflation)	0.025	0.432***	0.596***	0.208***	—			
Expectation bias (High inflation)	-0.23***	0.621***	0.416***	-0.344***	-0.05***	—		
Purchase adaptation	0.067***	0.099***	0.136***	0.025	0.071***	0.064***	—	
Final savings	0.201***	-0.151***	0.027	0.139***	0.106***	-0.257***	0.051***	—

3.3.4. Real life vs. Savings Game

In our inflation awareness questionnaire, when assessing subjects' responses to how they would adjust behavior if prices increased in the ensuing 12 periods, we observe a lack of adaptation to inflation in the answers. Most individuals do not expect to change their behavior at the time of the experiment (see Appendix A Table 4 and Appendix A Table 5 in Appendix A.1. Additional results). Given that the experiment takes place during still an early phase of inflation in real life in France, however, we are not surprised to see that subjects do not demonstrate adaptability to inflation in real life.

We observe no correlation between individual answers in real life and performance measures. This is also not surprising given subjects' inconsistent answers in the questionnaire.

Nevertheless, as per Table 6, there are noteworthy correlations between inflation perceptions and expectations biases in real life and the Savings Game. Firstly, subjects show consistency in the correlations between their perception and expectation biases.

Real life expectation biases correlate positively by 0.57 and 0.85 ($p \leq 0.01$) to real life perception bias.[4] Savings Game-based expectation biases similarly correlate positively by 0.74 and 0.76 ($p \leq 0.01$) for low and high inflation phases respectively. Secondly, we observe positive correlations ($p \leq 0.01$) between real life and Savings Game biases, of both perceptions and expectations. The correlation is especially strong between low-inflation perception biases in the Savings Game and real-life perception biases, which makes sense considering they relate to similar inflationary conditions; high inflation in the Savings Game is a magnitude of order higher than the "high" inflation experienced in France at the time of the experiment. This suggests that the Savings Game has external validity, successfully eliciting similar perception and expectation tendencies from subjects to those they demonstrate in real life. See Appendix A Table 6 in Appendix A.1. Additional results for subjects' reported perceived and expected inflation in real life.

Table 6 - Correlations between in-task and real-life expected and perceived inflation measures

	Real life, Highest inflation	Real life, Lowest inflation	Real life, Last 12 months	Real life, Current inflation	Real life, Next 12 periods	In-task, Expectation bias, Low	In-task, Expectation bias, High	In-task, Perception bias, Low	In-task, Perception bias, High
Real life, Highest inflation	—								
Real life, Lowest inflation	0.21*	—							
Real life, Last 12 months	0.55***	0.24*	—						
Real life, Current inflation	0.64***	0.24*	0.79***	—					
Real life, Next 12 periods	0.39***	0.09	0.85***	0.57***	—				
In-task, Expectation bias, Low	0.2*	-0.11	0.34***	0.3**	0.35***	—			
In-task, Expectation bias, High	0.22*	-0.04	0.35***	0.33***	0.34***	0.86***	—		
In-task, Perception bias, Low	0.29**	0.04	0.51***	0.49***	0.49***	0.74***	0.72***	—	
In-task, Perception bias, High	0.13	-0.0	0.33***	0.35***	0.25*	0.67***	0.76***	0.6***	—

[4] We correlate to perceptions as both subjects' estimates of the "current" inflation rate as well as the rate over the "last 12 months," which should be equal.

3.3.5. Regression of initial performance

To further analyze the relationship between subjects' initial performance for each inflation sequence (i.e. the first two sessions) and the relation to the inflation measures, we conduct an ordinary least squares regression (OLS) to understand the ratios of total final savings, over-stocking, and wasteful-stock to the maximum savings via the best strategy. Table 7 shows the results.

Firstly, in terms of overall ("total") performance, we find further confirmation that the 10x12 sequence is more difficult, whereby performance is lower by over 17% of the maximum savings ($p \leq 0.01$). We also see that facing 10x12 in the second session as opposed to the first is beneficial, leading to a higher final savings by an additional 17% of the maximum savings ($p \leq 0.01$). The 10x12 sequence also relates negatively to over-stocking ($p < 0.1$), which makes sense since there is a smaller window to over-stock initially. But, over-stocking increases in the second session by 19% of maximum savings ($p \leq 0.01$), indicating that subjects are pessimistic about inflation after having experienced the first session. Furthermore, perception sensitivity relates positively to overall performance ($p \leq 0.01$) and negatively to both over- ($p \leq 0.1$) and wasteful-stocking ($p \leq 0.01$) costs, which further validates the importance of an accurate understanding of inflation for success in the Savings Game.

Table 7 - OLS regressions of performance measures in first two sessions

Variables	(1) Final savings (%)	(2) Over-stock (%)	(3) Wasteful-stock (%)
Intercept	0.4073***	0.2681***	0.1760***
	(0.0404)	(0.0376)	(0.0285)
Inflation, 10x12	-0.1731***	-0.0652*	-0.0476
	(0.0414)	(0.0385)	(0.0291)
Day 2	-0.0644	0.1898***	-0.0437
	(0.0405)	(0.0376)	(0.0285)
Inflation, 10x12 × Day 2	0.1681***	-0.0751	0.0009
	(0.0575)	(0.0534)	(0.0405)
Expectation sensitivity	0.0255	-0.0618	0.0226
	(0.0408)	(0.0379)	(0.0287)
Expectation bias	0.0008	0.0001	0.0002
	(0.0009)	(0.0008)	(0.0006)
Perception sensitivity	0.1726***	-0.0820*	-0.1145***
	(0.0458)	(0.0425)	(0.0322)
Perception bias	-0.0004	0.0003	-0.0001
	(0.0005)	(0.0005)	(0.0004)
R-squared	0.1673	0.2215	0.0945
R-squared Adj.	0.1380	0.1941	0.0626

Standard errors in parentheses.

* p<.1, ** p<.05, *** p<.01

3.4. The role of individual preferences, knowledge, cognitive flexibility and inconsistent choice behavior

3.4.1. Correlations with individual characteristics

We now assess Hypothesis 2, that heterogeneity of behavior in the Savings Game can be explained by differences in individual characteristics. To this end, we examine the relationship between subjects' responses to the battery of additional tests and their performance in the Savings Game.

From the three knowledge measures, we find that 58% of subjects are financially literate, 24% are numerate, and 51% are compound interest-capable.

We elicit subjects' seven preferences via the tests described in Section 2.3.3. Appendix A Table 3 in Appendix A.1. Additional results shows the mean and standard deviation for each preference task. As mentioned previously, for risk aversion, loss aversion, and time preferences, we include a measure that counts the number of "switches" a subject makes, where more than one switch for a given series of choices suggests a subject has inconsistent preferences (Kurtz-David et al., 2019). Note that for time preferences, consistent choice behavior results in three switches since there are three choice sets.

We correlate these individual characteristics and preferences with the four performance measures as well as the in-task inflation measures. Further, we apply a Bonferroni correction to account for the interdependence between the performance measures (i.e. an increase in over-stocking cost by definition reduces final savings). The results in the tables below exhibit only the statistically significant correlations with p values below the Bonferroni-corrected threshold.

For knowledge measures in Table 8, we find positive correlations between final savings and all three knowledge measures ($p \leq 0.01$). We also find a positive correlation between numeracy and purchase adaptation ($p \leq 0.01$).

Table 8 -Correlations between knowledge and performance measures (with Bonferroni correction)

Characteristic	Performance measure	Correlation	p value
Financially literate	Final savings (%)	0.2870	0.0031
Numerate	Final savings (%)	0.2711	0.0054
Compound interest-capable	Final savings (%)	0.2929	0.0025
Numerate	Purchase adaptation	0.2632	0.0070

We find no statistically significant correlations between neither the adaptability measures (i.e. Wisconsin card sorting task) nor the four economic preferences and any of the performance measures. However, in Table 9, we see negative correlations between the number of time preference- and risk-related switches and final savings. We also find positive correlations between the inconsistency of economic decisions and wasteful-stock costs. These results are intuitive, considering that wasteful-stock costs are the most incoherent mistake from the perspective of economically rational decision-making within the task, particularly considering that they do not relate to inflation.

Table 9 - Correlations between inconsistencies in economic preferences and performance measures (with Bonferroni correction)

Characteristic	Performance measure	Correlation	p value
Loss aversion, number of switches	Wasteful-stock cost (%)	0.3034	0.0017
Risk aversion, number of switches	Final savings (%)	-0.2754	0.0047
Risk aversion, number of switches	Wasteful-stock cost (%)	0.3451	0.0003
Time preferences, number of switches	Final savings (%)	-0.3675	0.0001
Time preferences, number of switches	Wasteful-stock cost (%)	0.3284	0.0007

Correlating the inflation bias and sensitivity with knowledge measures in Table 10, we observe positive correlations between numeracy and compound interest-capability with perception sensitivity ($p \leq 0.01$). We also find a positive correlation between compound interest-capability and perception bias ($p \leq 0.01$). These results suggest that numerical abilities do indeed correlate with individuals' perceptions of inflation.

Table 10 - Correlations between knowledge and inflation bias and sensitivity measures (with Bonferroni correction)

Characteristic	Performance measure	Correlation	p value
Numerate	Perception sensitivity	0.3684	0.0001
Compound interest-capable	Perception sensitivity	0.4140	0.0000
Compound interest-capable	Perception bias	0.3181	0.0010

Once again, we find no correlation between the economic preferences and inflation measures. In Table 11, we do, however, find a negative correlation between the number of risk-related switches and perception sensitivity ($p \leq 0.01$) and positive correlation between risk-related switches and expectation bias ($p \leq 0.01$). The correlation between perception sensitivity. We also find a positive correlation between adaptability as measured by the WCST and perception sensitivity ($p \leq 0.01$). The correlations with the number of switches suggest a connection between inconsistency of economic decisions and less precise perceptions and expectations, while adaptability appears to relate positively to individuals' abilities to perceive the changes in inflation.

Table 11 - Correlations between inconsistency and inflation bias and sensitivity measures (with Bonferroni correction)

Characteristic measure	Performance measure	Correlation	p value
Risk aversion, number of switches	Perception sensitivity	-0.3472	0.0003
Risk aversion, number of switches	Expectation bias	0.3161	0.0011
Wisconsin card sorting task, number correct	Perception sensitivity	0.2793	0.0041

3.4.2. Regression on individual characteristics

Next, we conduct an OLS regression of the performance measures on the individual characteristics, using a forward selection algorithm that maximizes the adjusted R^2 of each model (Lindsey & Sheather, 2010). Table 12 shows the results of regressions for final savings, over-stocking, and wasteful-stock relative to the maximum. Only algorithm-selected variables appear. We find that expectation sensitivity relates positively to final savings ($p \leq 0.1$), and overall inconsistency in economic decisions (i.e. total switches) relates negatively ($p \leq 0.01$). The procedure further produces a model for over-stocking with a negative relationship between numeracy ($p \leq 0.1$) and over-stocking but positive between financial literacy and over-stocking ($p \leq 0.05$). Finally, for wasteful-stocking, we find a positive relationship with the inconsistency of economic preferences ($p \leq 0.01$) and, interestingly, with age ($p \leq 0.01$); although, the relationship with age is weak.

Admittedly, this is a heuristic method to see which of the many variables measuring different individual characteristics. Nevertheless, it is interesting to see in the resulting regression models that expectation sensitivity, financial literacy, numeracy, and inconsistency of economic preferences demonstrate strong influence. Of particular note, the positive relationship between financial literacy and over-stocking, while initially counterintuitive, may demonstrate how financially literate subjects were concerned primarily with economizing—avoiding higher prices in the future—but were overly pessimistic about and/or actually overestimated inflation.

Overall, these correlations and regression provide support for Hypothesis 2, that heterogeneity of behavior in the experimental task (i.e. performance) can be explained by differences in individual characteristics. More specifically, the most relevant characteristics include numerical abilities (i.e. numeracy and compound-interest capability), financial literacy, and consistency of economic decisions.

Table 12 - Forward-selected OLS regressions of performance measures from first two sessions

Variables	**(1)** **Final savings (%)**	**(2)** **Over-stock (%)**	**(3)** **Wasteful-stock (%)**
Intercept	0.6550***	0.4645***	-0.2101***
	(0.0662)	(0.1014)	(0.0545)
Compound	0.0518		
	(0.0320)		
Financially literate		0.0706**	
		(0.0342)	
Numerate	0.0321	-0.0782*	
	(0.0373)	(0.0401)	
Age		-0.0024	0.0034***
		(0.0017)	(0.0012)
Education level		-0.0293	
		(0.0231)	
Expectation sensitivity, pre-treatment	0.1039*	-0.1076	
	(0.0625)	(0.0701)	
Monthly income	-0.0000		
	(0.0000)		
Can save			-0.0339
			(0.0312)
Total switches	-0.0275***		0.0300***
	(0.0065)		(0.0051)
Risk aversion, safe choices	-0.0095		
	(0.0066)		
Time preferences, smaller-sooner choices	-0.0033		0.0025
	(0.0022)		(0.0018)
WCST, number correct		-0.0033	
		(0.0024)	
R-squared	0.3396	0.1257	0.3320
R-squared Adj.	0.2915	0.0716	0.3051

Standard errors in parentheses.

* p<.1, ** p<.05, *** p<.01

3.5. Learning and Intervention

3.5.1. Differences in performance change

We now investigate support for Hypothesis 3, that subjects are capable of improving their behavior through learning and a financial-education intervention. First, we assess a potential learning effect then potential treatment effect between sessions through difference-in-difference measures. Specifically, we take the mean difference in change for each measure (final savings, over- and wasteful-stocking costs, and consumption change) between the first two and second two sessions. For the intervention, we calculate the difference-in-difference between the treatment and control group.

Across all subjects, we find a 9% overall increase in performance relative to the maximum ($p \leq 0.05$) and 4% decrease in wasteful-stocking costs relative to the maximum ($p \leq 0.01$). We also observe an increase in expectation sensitivity ($p \leq 0.05$), suggesting that subjects learn to anticipate the price increases over the four sessions. Taken together, we conclude that there is a learning effect over the course of the experiment.

Table 13 - Change in performance between first and second two sessions

	Final savings (%)	Over-stock (%)	Wasteful-stock (%)	Purchase adaptation	Perception sensitivity	Perception bias	Expectation sensitivity	Expectation bias
Mean difference	0.09**	0.06	-0.04***	0.32	0.03	-1.2	0.08**	-1.44
(std)	(0.37)	(0.39)	(0.2)	(5.71)	(0.23)	(23.43)	(0.32)	(16.26)

Being the case, though, as Table 14 shows, we do not find any statistically significant difference in the change in performance between the intervention and control groups.

Table 14 - Change in performance among treatment groups

	Final savings (%)	**Over-stock (%)**	**Wasteful-stock (%)**	**Purchase adaptation**	**Perception sensitivity**	**Perception bias**	**Expectation sensitivity**	**Expectation bias**
Mean (control)	0.07	0.07	-0.03	0.13	0.11	1.04	0.02	-1.35
Mean (intervention)	0.11	0.04	-0.05	0.52	0.05	-3.92	0.05	-1.05
Mean difference	0.04	-0.03	-0.02	0.39	-0.06	-4.96	0.03	0.3

Investigating further, we analyze the intervention's impact per individuals' knowledge and economic preferences to see if there is a heterogeneous impact according to particular characteristics.

While we find no statistically significant difference in impact from the financial education intervention on financially literate and illiterate subjects, we do find the intervention has an impact on numerate subjects ($p \leq 0.05$), who reduce their over-stocking cost compared to the innumerate (Table 15). Similarly, we find the intervention has an impact on compound interest-capable subjects ($p \leq 0.01$), helping reduce both their early costs and perception bias (Table 16).

Furthermore, we observe improvement amongst more adaptive subjects (identified by a median split of the number of correct selections in the Wisconsin card sorting task) receiving the intervention as compared to their less adaptive counterparts in total performance (Table 17).

Overall, these findings suggest that the intervention only produced impact for the subjects identified as the most numerically capable and behaviorally adaptive. Both such findings make sense. More numerically capable subjects are better equipped to not only better perceive the change in inflation through prices alone, but also concretely understand the value of saving during periods of positive real interest as opposed to over-stocking. Further, adaptive subjects may simply be more inclined to adopt novel practices.

Table 15 - Difference between numerate and innumerate with intervention

	Final savings (%)	Over-stock (%)	Wasteful-stock (%)	Purchase adaptation	Perception sensitivity	Perception bias	Expectation sensitivity	Expectation bias
Mean (not numerate)	0.13	0.14	-0.05	0.75	0.07	1.11	0.03	-5.42
Mean (numerate)	0.08	-0.17	-0.03	0.05	0.00	-5.50	0.08	-0.84
Mean difference	-0.05	-0.31**	0.03	-0.70	-0.07	-6.61	0.05	4.58

Table 16 - Difference between compound interest capable and compound interest incapable with intervention

	Final savings (%)	Over-stock (%)	Wasteful-stock (%)	Purchase adaptation	Perception sensitivity	Perception bias	Expectation sensitivity	Expectation bias
Mean (incapable)	0.09	0.24	-0.03	0.80	0.05	11.90	0.01	-1.80
Mean (capable)	0.14	-0.14	-0.06	0.27	0.05	-13.04	0.08	-5.89
Mean difference	0.05	-0.38***	-0.02	-0.53	0.00	-24.94***	0.07	-4.09

Table 17 - Difference between more adaptive and less adaptive with intervention

	Final savings (%)	Over-stock (%)	Wasteful-stock (%)	Purchase adaptation	Perception sensitivity	Perception bias	Expectation sensitivity	Expectation bias
Mean (below median)	0.03	0.08	-0.01	-0.65	0.01	-3.23	0.08	-6.08
Mean (above median)	0.20	0.00	-0.08	1.70	0.09	-4.61	0.01	3.98
Mean difference	0.17**	-0.08	-0.08	2.35	0.08	-1.38	-0.07	10.06

3.5.2. Regression of performance on intervention

We repeat the OLS regressions on performance measures now with the intervention to assess the treatment’s impact. Appendix A Table 7 in Appendix A.1. Additional results shows the results. As can be seen, the intervention does not demonstrate improvement. We also note that session 2 and 4 both produce high over-stocking ($p \leq 0.01, p \leq 0.05$), which may imply that the pessimism about inflation subjects gain after session 1 is reinforced after session 3. More interestingly, though, the results reiterate the importance of subjects' inflation beliefs, where perception sensitivity continues to be a strong indicator of good performance ($p \leq 0.01$).

Next, we repeat the forward selection algorithm with the intervention as an additional variable. Appendix A Table 8 in Appendix A.1. Additional results shows the models the algorithm produces. The intervention variable does not demonstrate statistically significant impact, as expected per the overall difference in performance change between treatment groups from Table 14. That said, we find a positive interaction term with adaptability per the WCST ($p \leq 0.05$) for final savings; however, the interaction terms of numeracy and compound interest are not selected by the algorithm. At the very least, this seems consistent with the overall unconvincing impact from the intervention.

4. DISCUSSION

Below, we assess our initial hypotheses as well as additional advances that our experiment demonstrates and further research questions that arise from our results.

4.1. Hypotheses

The present experiment aims to test the hypotheses that:

1. subjects do not perform well in the inflation task, and less accurate perceptions and expectations of inflation correlate to a lower performance in the task and, thus, less adaptability to inflation,
2. heterogeneity of behavior in the experimental task can be explained by differences in individual characteristics, and
3. subjects are capable of improving their behavior through learning and a financial-education intervention.

Considering the results above, we confirm Hypothesis 1. Subjects perform well below the maximum benchmark, especially in the 10x12 sequence, which proves to be more difficult. Furthermore, not only do we find consistent correlations between subjects' perceptions and expectations of inflation and their overall performance as well as purchase adaptation, but these inflation measures demonstrate relatively strong predictive power in our regressions of performance as well.

Regarding Hypothesis 2, having measured a number of individual characteristics, there are a few that appear to consistently relate to performance. Numeracy and compound-interest capability demonstrate clear positive correlations across a number of measures as well as demonstrate relatively important roles in the regression models. Conversely, subjects' inconsistency of economic decisions clearly correlates with worse performance across the measures as well as plays a negative role in the regression models. These characteristics make intuitive sense. Ultimately, the Savings Game requires numerical information processing. The only information subjects have to deduce inflation is that of prices, and they need to consider opportunity costs for each savings-purchase decision. Being the case, those with more switches in the economic preference tasks demonstrate less consistency in economic decision-making as a whole, which also naturally risks lowering performance.

Finally, for Hypothesis 3, although we do confirm a learning effect over the course of the four sessions, we do not find an overall impact from the intervention.

4.2. General analysis

Beyond confirming our first two hypotheses and partially confirming the third, the results of our experiment provide validation of our research approach and experimental procedure, allowing us to address additional challenges that the literature on inflation and behavior has faced.

First of all, our experiment demonstrates that it is logistically possible to conduct multi-day experiments online. At the end of the four days, we have an 88% completion rate among subjects, meaning only 12% did not complete the full, four-session procedure. This validation of the multi-day procedure offers new possibilities for studying behavior online over time, a more cost-effective and scalable method than in-person laboratory experimentation methods.

Second, there exists a valid debate as to how much of the heterogeneity between households' inflation perceptions and expectations is due to differences in their perceptions and/or expectations as opposed to differences in the actual, personal inflation rate each household faces. This doubt arises since each household, in fact, purchases a unique basket of goods, which may not be accurately reflected in the headline inflation rate to which their perceptions and expectations are compared (Ranyard et al., 2008). By restricting the information on inflation in the Savings Game to simply the changes in price of a single good, we ensure that all subjects face exactly the same inflationary environment and information set. As a result, we are sure that the biases subjects exhibit as well as the heterogeneity of estimations between subjects are indeed the result of divergences from the actual inflation rate—and not merely reflections of differences in the true personal inflation rates each subject faces since we know there is a significative heterogeneity across households. For instance, low-income, rural, and senior households were the most affected by recent inflation in OECD countries (Causa et al., 2022).

More generally, though, the Savings Game successfully distills into a controlled experimental environment the key components of the inflationary experience that household decision-makers face. By remunerating subjects for their final savings balance while conditioning success or failure on their consumption, we force them to explicitly face the trade-off between building and protecting wealth and economizing their purchases. As such, we can replicate and isolate the consumption-savings decisions that subjects make in real life when facing rising prices and directly link their behavior to their perceptions and expectations of inflation, which the existing literature has been unable to achieve.

Furthermore, comparing the experimentally elicited perceptions and expectations of inflation to subjects' real-life estimates, we observe similar biases and, indeed, strong correlations between the in-task and real-life. These findings suggest that the Savings

Game does in fact provide external validity in capturing subjects' biases. This external validity also adds weight to the validity of the consumption and savings behaviors we measure in the task, particularly as they relate to inflation perceptions and expectations and the biases underlying them. Therefore, we can further confirm that we achieve our objective of providing the missing micro-level behavioral data required to better understand the relationship between perceptions and expectations of inflation and behavior at the individual level.

4.3. Further investigation

Our results highlight that perceptions and expectations do appear to play an important role in overall performance. Thus, it is noteworthy that subjects demonstrate such large biases in their perceptions and expectations. Two questions arise from this point. First, as Andrade et al. (2023) note, qualitative estimates (i.e. simply saying whether prices increased or decreased, rather than giving a point estimate) may offer better indicators. Second, our slider measurement method, while aiming to offer an unbiased tool, may be too cumbersome for subjects to provide precise estimates; that is to say that they do not take the time to drag the slider to the exact value of their estimate. Measuring qualitative estimates as well as improving the estimate elicitation method is, therefore, one area of improvement for the Savings Game.

An additional challenge arising from the performances in the experiment is explaining the high levels of over-stocking subjects demonstrate in the first periods. Because we only measure their inflation expectations after period $t = 12$, we cannot directly assess whether this early over-stocking relates to their pessimism about, and thus high expectations of, inflation from the start. Therefore, an additional improvement that can be made would be to measure expectations at period $t = 1$ and compare them to over-stocking behavior to see if there is indeed a correlation.

The lack of impact by our intervention, a simple financial education, is ultimately consistent with much research in the field, which demonstrates the challenge financial education faces in improving decision-making (Lusardi, 2008; Mandell & Klein, 2009;

Stolper & Walter, 2017). Reflecting on the method and information, two aspects become apparent in regards to offering an effective educational experience. First, subjects do not receive any information or feedback regarding their performance, particularly how poorly they may have performed compared to the maximum possible. As a result, they may not recognize just how much they diverge from the recommended strategy and, thus, believe that they already do what the intervention suggests or that they do not need to improve and so do not heed the advice offered. Indeed, as Georganas et al. (2014) observe, individuals rarely receive feedback on their savings-consumption decisions and, as a result, rarely feel the need to improve their decision-making habits. Therefore, providing clear feedback may be necessary to improving an intervention's efficacy.

Second, the explanation of the concepts and strategy may be too theoretical, not offering practical steps to take during the game. As a result, subjects may not understand the information or not be able to put the information into practical steps in the Savings Game. A more effective intervention might include not just feedback on subjects' performance but guidance to better understand where they make mistake, how those mistakes impact them, and a practical explanation of how to implement the recommended strategy.

Being the case, there are a number of clear steps forward to advance this research in inflation and behavior via experimental methods further.

Chapter 2:
Experimental analysis of survey-based inflation measures and dynamic financial education[5]

We conduct an online experiment to assess the validity of the survey-based methods used by central banks and in macroeconomic research to measure inflation perceptions and expectations as well as test dynamic financial education interventions to improve household consumers' decision-making in inflationary conditions. Employing the intertemporal savings and consumption task known as the Savings Game (Lawrence et al., n.d.), we test how well survey-based measures of inflation internalization (i.e. perceptions and expectations) correlate with and ultimately predict consumers' behavior when facing inflation. We also confirm the primary individual characteristics that relate to better adaptability and performance in the Savings Game. Further, considering the lack of impact generic financial education treatments have on subjects' in-task performance, we test how dynamic, personalized feedback and guidance impacts behavior. We find strong evidence confirming that survey methods provide valid measures, which indeed correlate with behavior (particularly qualitative internalizations); that subjects' numerical abilities, consistency of economic decision-making, and general adaptability are the primary individual-characteristic indicators of performance; and that treatments with dynamic, personalized feedback coupled with straightforward and actionable recommendations do improve subjects' decision-making and performance.

[5] This chapter is based off Lawrence, N., Guille, M., & Vergnaud, J.-C. (n.d.). *Experimental analysis of survey-based inflation measures and dynamic financial education* (LEMMA Working Paper). Université Paris-Panthéon-Assas, LEMMA.

1. INTRODUCTION

With inflation a now resurgent issue in households' daily lives and decisions, understanding how rising prices and consumer behavior relate has become increasingly important. Over the last few decades, however, there has been limited research into both inflation—since it has been relatively absent from developed economies—as well as methods to help households better manage their finances when facing rising prices.

Within the limited contemporary literature on inflation, the primary focus has been on the perceptions and expectations of inflation—*inflation internalization*. A small subset of the inflation literature has additionally investigated the relationship between household consumers' inflation internalization and their economic behavior. This research, however, primarily consists of macroeconomic analyses and, moreover, has found conflicting patterns (Gautier & Montornès, 2022). These inconsistent results may partly arise from comparisons across economies and time periods. But, in addition, this research typically uses survey methods, which can differ in methodologies, even simply in question wording, which presents another potentially confounding factor throughout the literature (Van Der Klaauw et al., 2008).

Households' inflation perceptions and expectations are difficult to measure by any means other than survey approaches (Gautier & Montornès, 2022). Being the case, though, comparing such perceptions and expectations to empirical economic behavior becomes difficult since most surveys cannot follow individual households for long, let alone consistently track their economic behavior. As a result, most analyses of the relationship between inflation internalization and consumer behavior rely on survey responses not only for perception and expectation data but for behavioral data as well. For instance, durables consumption is often measured simply through survey responses to having made any large purchases over the previous 12 months. This method poses significant data integrity challenges since the research ultimately relies on respondents accurately remembering a year's worth of consumption. Realistically speaking, though, there are few alternatives to effectively pair inflation estimations with economic behavior.

One such alternative is ad-hoc surveys that have been fielded, which match survey responses with corresponding micro-level data (D'Acunto et al., 2022). For example, the Chicago Booth Expectations and Attitudes Survey (CBEAS) and Chicago Booth Expectations and Communication Survey (CBECS) combine the Kilts-Nielsen Consumer Panel (KNCP), which captures non-durable consumption through scanner data, with broad surveys on economic choices and expectations (Coibion, Gorodnichenko, et al., 2021; D'Acunto et al., 2022). While such methods can provide micro-level data necessary to properly compare perceptions and real-life behavior, they are also highly resource intensive and therefore difficult to replicate. Further, they provide data only for a limited time period.

Another issue arising from the current approach is estimation precision and/or accuracy. Although ultimately necessary, relying on survey responses from households presents clear problems when it comes to the reliability of their answers. Two of the most widely used surveys, the Michigan Survey of Consumers (MSC) and Federal Reserve Bank of New York Survey of Consumer Expectations (SCE), both present high frequencies around inflation estimates in multiples of five, suggesting a degree of uncertainty or at the very least imprecision in responses (Binder, 2017). Adding density forecast questions to surveys has offered one solution to this issue of response uncertainty, including in the SCE now (Binder, 2017; Bruine de Bruin et al., 2011); however, these exercises in probability estimation are far from intuitive for most people. Surprisingly, the measure that appears to most closely correlate with macroeconomic trends is qualitative responses, where participants simply say whether they think/expect prices have increased/will increase, as opposed to quantitative estimates (Andrade et al., 2023).

Finally, considering the negative impact inflation can have on households' economic well-being, developing methods to help consumers protect themselves against rising prices is imperative. And, this is an area where survey approaches have been particularly limited. There have been some attempts to include information interventions in surveys, which have demonstrated improvements (albeit short-lived) in perception and expectation accuracy (Armantier et al., 2016; Coibion, Georgarakos, et al., 2021; Coibion, Gorodnichenko, et al., 2021). But, assessing any intervention's impact on households' economic behavior falls generally outside the scope of surveys.

Taken together, there persist three challenges to a more holistically analyzing and understanding the relationship between inflation internalization and behavior:

1. connecting households' inflation perception, expectation, and uncertainty in survey-based data to their economic behavior;
2. unpacking the interplay of qualitative, quantitative, and uncertain responses in the survey data; and
3. developing and testing an effective intervention to improve consumers' resilience against inflation.

Experimental economic methods offer an effective solution. Through an experimental approach, we can overcome these three challenges through granular data that is easily comparable across the subject population, as it is collected in a controlled environment. This presents an opportunity to both study behavior and interventions more closely at the individual level as well as validate macroeconomic, large-scale survey-based results.

In Chapter 1, we develop and test a novel intertemporal consumption simulation with changing inflationary conditions (the "Savings Game") to measure individuals' adaptability to inflation. We find that not only do subjects perform well below the maximum, but a significant portion of their underperformance results from their over-stocking in low-inflation and even stocking wastefully by purchasing more units of the good than necessary. Moreover, we find that:

- more accurate inflation perceptions and expectations correlate with better performance;
- subjects' who are numerate, capable of compound-interest calculation, and consistent in economic decision-making (i.e. few preference "switches") perform better; and
- a simple financial education intervention does not improve performance.

Ultimately, we find that subjects' in-task and real-life inflation perception and expectation capabilities are closely linked, suggesting that the Savings Game offers external validity. Building on the original experiment, our present study has two primary objectives. Our first objective is to better connect the behaviors we can measure in the Savings Game to the survey data normally collected in real-life. Our second is to identify a more effective intervention for improving the behavior of individuals facing inflation.

To better connect behavior and inflation internalization data, we simulate the survey method during the Savings Game by intermittently providing subjects with the inflation portion of a replica consumer survey questionnaire. The questionnaire is based off of France's Monthly consumer confidence survey (CAMME) for simple comparison to macroeconomic data and includes both qualitative and quantitative estimates. We then measure a proxy for estimation uncertainty by comparing the share of quantitative responses that are multiples of five (Binder, 2017; Gautier & Montornès, 2022; Reiche & Meyler, 2022). In general, this approach can allow us to:

- observe experimentally the relationships between inflation internalization (i.e. perception, expectation, and uncertainty) and consumption behavior and compare them to those observed macroeconomically as well as
- provide data on not only the self-reported consumption behaviors but on experimentally observed behavioral data too.

In our previous experiment, we found our simple financial education intervention—explaining the concepts of inflation and real interest rates and laying out the best strategy in terms of the real interest rate—was not sufficiently impactful. We hypothesize that not only was the information presented too theoretical, but much of that information fell on deaf ears because subjects never received feedback regarding their previous performance. Without such feedback, subjects failed to recognize that they in fact needed to improve—an issue consumers face in real life as well (Georganas et al., 2014).[6] To identify intervention methods that improve performance and decision-making, we test and compare two new interventions that provide dynamic, performance-based feedback based on their first session of the Savings Game.

Intervention 1 focuses on how subjects' performance compares to the maximum they could earn and ultimately be remunerated for and where they make mistakes, rather than on more general economic concepts and optimal strategies. The intervention explains the three types of errors they can commit (over-, under-, and wasteful-stocking[7]) and asks subjects if they believe they committed each of these mistakes, fostering self-reflection. *Intervention 2* builds on Intervention 1 while also more concretely explaining not only the step-by-step process to assess what kind of inflationary conditions one currently faces and what the appropriate decision is, but how the opportunity costs arise from each mistake as well.

As such, we conduct an experiment to test the following hypotheses that:

1. individuals' inflation survey responses
    a. correlate with their in-task economic behaviors as well as that
    b. qualitative inflation-estimate (perceptions and expectations) and estimation-uncertainty measures correlate better with in-task economic behavior than quantitative measures;
2. across a wide array of individual characteristics related to financial education and behavioral economics, the primary indicators of in-task performance are numeracy, adaptability,[8] and consistency of economic decision-making; and
3. an intervention with dynamic performance-based feedback can improve performance in the Savings Game.

[6] "Small mistakes in consumption-savings decisions, however, are unlikely to provide informative negative feedback. Thus, consumers will feel little to no pressure to adapt their method of aggregation" (Georganas et al., 2014)

[7] See Section 2.1.4. Performance and adaptation to changing inflation phases in Chapter 1 for an explanation of over-, under-, and wasteful-stocking.

[8] While the results of our initial experiment do not reveal adaptability to be a primary indicator, considering that the Savings Game inherently requires adaptability, we decide to continue investigating this potential relationship. In particular, our previous experiment may have lacked statistical power with the limited number of observations.

2. METHOD

2.1. Experimental procedure

The interface is developed using oTree, an open-source software development framework built on Python and Django (Chen et al., 2016). We conduct the experiment online in French using the hosting services of the S2CH Research Federation. We recruit subjects from the volunteer pool of the Laboratory of Experimental Economics in Paris (LEEP) through an online system (ORSEE).

The experiment takes place online over the course of one day for each subject, with multiple sessions run over the course of three weeks. Subjects first complete a questionnaire and a battery of knowledge and economic preference tests, the order of which is randomly assigned. Then, they receive instructions on how to play the Savings Game and complete the first of two rounds of the Savings Game. Afterwards, they receive their assigned treatment (Intervention 1, Intervention 2, or control[9]) and then play the second round of the Savings Game. On average, the experimental session takes about one and a half hours.

Subjects received a €5 participation fee as well as remuneration for their performance in the Savings Game and Wisconsin card sorting, Holt & Laury lottery, and lottery with loss tasks. Remuneration was only paid, however, if the subject completed all tasks in the session. The experimental currency unit was represented using the "₮" symbol, which had an exchange rate of ₮750 = €1.

[9] The control consisted of receiving the numeracy and time preference tests in random order in between round 1 and round 2 of the Savings Game, rather than one of the interventions.

2.1.1. Savings Game parameters

We use the following parameters within the Savings Game for this experiment, which are the same as the previous experiment:

- initial endowment of ₮863.81,
- per-period income of ₮4.32,
- savings account interest rate of 1.9% per period,
- initial price of the good of ₮8.07.

Both rounds of the Savings Game follow the 4x30 inflation sequence, which alternates twice between a low- and high-inflation phase, each 30 periods long, over the course of 120 periods. In this 4x30 sequence, low-inflation phases produce an average per-period inflation of 0.04% and low variability (between 0.00% and 0.08%), and high-inflation produces an average per-period inflation of 4.2% and higher variability (between 0.3% and 6.3%).

See Sections 2.1.1. Main rules and 2.1.2. Experimental parameters in Chapter 1 for a complete explanation of the rules of the Savings Game.

2.1.2. Inflation survey

To replicate the large-scale inflation survey methods used to produce perceived and expected inflation rates in real-life, we ask subjects questions based off the CAMME survey currently used in France. As per the CAMME procedure, subjects first must provide a qualitative estimate of their inflation perception by answering the question "Do you find that, over the past twelve months, prices have..."[10] with one of the following multiple-choice options:

[10] The English translation provided here is per Andrade et al. (2023).

- Increased rapidly
- Increased moderately
- Increased slightly
- Stayed the same
- Decreased

If subjects chose “Stayed the same,” they proceed to the next period in the Savings Game; otherwise, they must then provide a *quantitative estimate* of the percentage by which they think prices changed.

We elicit inflation perceptions every twelve periods, starting at period $t = 12$ and ending at period $t = 120$.

We repeat this procedure for inflation expectations as well. Subject first provide a *qualitative estimate* of their inflation expectation, by answering a modified version of the inflation expectations question from the CAMME survey: “How do you expect prices to evolve over the next twelve months?”[11] Similar to qualitative perceptions, they can respond one of the following multiple-choice options:

- They will increase quickly
- They will increase moderately
- They will increase slowly
- They will stay the same
- They will decrease

If subjects chose “They will stay the same,” they proceed to the next period in the Savings Game; otherwise, they must then provide a *quantitative estimate* of the percentage by which they think prices will change.

[11] We must modify the question from its original form “In comparison with the past 12 months, how do you expect consumer prices will develop in the next 12 months? They will...” since we ask subjects for their expectations at period $t = 1$ to which they cannot compare any previous price changes. As a result, we must also adjust the original CAMME answer options: “increase more rapidly,” “increase at the same rate,” “increase at a slower rate,” “stay about the same,” or “fall” (Andrade et al., 2023). To maintain consistency and, thus, the comparability of the responses throughout the Savings Game, we maintain the question in its modified form.

We elicit a first inflation expectation estimate at the end of period $t = 1$, regarding subjects' expectations in the range of periods $2 \leq t \leq 12$, to overcome a challenge in our previous experiment. In our previous experiment, we measure inflation expectations for the first time at period $t = 12$, which restricts us from correlating their behavior in the first twelve periods to their inflation expectations at the start of the Savings Game round. Subsequently, we elicit inflation expectations every twelve periods, from $t = 12$ to $t = 108$.

2.2. Measures of inflation internalization

2.2.1. Quantitative estimation

To measure subjects' abilities to *quantitatively* perceive and anticipate inflation, we use the bias (overall and low- and high-inflation) and sensitivity measures Chapter 1. A positive (negative) bias represents an overestimation (underestimation) of perceived and expected inflation. The closer a subject's sensitivity to 1, the more accurately their estimations tracked the changes in inflation, whereas the closer to 0, the less they tracked inflation changes and the closer to -1, the more their estimations diverged.

2.2.2. Qualitative estimation

To measure subjects' abilities to *qualitatively* perceive and anticipate inflation, we measure the average accuracy of their estimation. We determine an accurate qualitative expectation as answering either "They will stay the same" or "They will increase slowly" just before or during low-inflation phases and "They will increase moderately" or "They will increase quickly" just before or during high-inflation phases. Similarly, we determine accurate qualitative perceptions as answering either "Stayed the same" or "Increased slightly" during or following low-inflation phases and "Increased moderately" or "Increased rapidly" during or following high-inflation phases. A subjects' average accuracy, therefore, is the percentage of accurate qualitative estimates they made among the ten in total that they must provide over the course of a round of the Savings Game.

2.2.3. Measure of estimation uncertainty

In our previous experiment, we are unable to produce a measure of uncertainty since the slider-based elicitation method we use does not ensure sufficient precision in the quantitative estimate subjects provide to evaluate their estimation certainty. With the survey-style method, whereby subject must directly type their point estimate, we gain this precision. Thus, we also introduce a measure of estimation uncertainty based Krifka's (2009) Round Numbers Round Interpretation Principle (RNRI), whereby one can interpret estimates in multiples of five as signal of estimation uncertainty (Binder, 2017; Reiche & Meyler, 2022). We therefore designate each estimation that is a multiple five as "uncertain" and calculate the percentage of responses that are uncertain.

2.3. Measures of individual characteristics

The measures of individual characteristics are nearly identical to those from Chapter 1. The knowledge measures include:

- financial literacy, using the "Big Three" questions from Lusardi and Mitchell (2009);[12]
- numeracy, using the adaptive version of the Berlin Numeracy Test (Cokely et al., 2012); and
- ability to calculate compound interest, using the compound interest questions from Macchia et al. (2018).

The economic preference measures include:

[12] We do not include the additional question from Arrondel and Masson (2014).

- time preferences, using an intertemporal randomized choice sequence similar to Cohen et al. (2016) that presents subjects with choices between smaller-sooner and larger-later payments in two sets, one on a one-month time horizon and one on a one-year horizon;
- risk aversion, using a Holt and Laury (2002) lottery choice procedure;
- loss aversion, using a lottery choice task with loss, similar to Gächter, Johnson, and Herrmann (2022); and
- adaptability to changing environments, using a Wisconsin card sorting task (Axelrod et al., 1992; Leshem & Glicksohn, 2007).

Additionally, we develop proxy measures for subjects' inconsistency in economic decision-making (Kurtz-David et al., 2019) based on the number of times the subjects make conflicting choices during the time preferences and risk and loss aversion tasks. More specifically, we count the number of times they switch from one preference to the other. In each task, an economically consistent individual should only switch once.[13]

For the Wisconsin card sorting task (WCST), we also measure perseverative and set-loss errors (Kopp et al., 2021). Perseverative errors occur when subjects select the same card characteristic despite just having received negative feedback about that characteristic in the previous decision. Set-loss errors represent incorrect guesses in the WCST despite receiving feedback of a correct decision for the previous card.

2.4. Interventions

Subjects are randomly assigned to one of three treatment groups: Intervention 1, Intervention 2, or control.[14] The interventions aim to provide dynamic, performance-based feedback to subjects as well as concrete, practical explanations—as opposed to

[13] In the time preferences task, since subjects face two sets of choices, up to two switches would represent consistency.
[14] For hands-on demos of Intervention 1 and Intervention 2, visit https://savingsgame.org/demo/intervention_1 and https://savingsgame.org/demo/intervention_2 respectively.

the theoretical explanations that subjects receive in our previous experiment in Chapter 1.

Intervention 1 first informs subjects the maximum savings they could have achieved in round 1, providing them the total opportunity cost they incurred through their mistakes of either over-, under-, or wasteful-stocking. The intervention explains that appropriate stocking requires knowing whether one is in a low- or high-inflation phase and offers guidance to assess inflation using a simple price comparison. Afterwards, the interventions describe how mistake can occur and how they each relate to the relationship between inflation and the interest rate. After explaining each mistake, subjects are asked if they believe they made the given mistake and then responds whether or not they are correct and offers a piece of advice as to how they can avoid the mistake in the next round. As an attention check, we then ask subjects if they are convinced by the feedback.

Intervention 2 builds on Intervention 1. Additionally, prior to the feedback section, Intervention 2 provides, a concrete explanation of:

- when subjects should save or stock up on the good as a function of when the inflation rate is greater than or less than the interest rate earned on the savings account,
- the opportunity cost of stocking or savings inappropriately, and
- how to estimate the inflation rate.

See Appendix B.1. Interventions for a complete description of each intervention.

2.5. Hypotheses

Thus, as described above, the present experiment aims to investigate the hypotheses that:

1. individuals' inflation survey responses
    a. correlate with their in-task economic behaviors as well as that
    b. qualitative inflation-estimate (perceptions and expectations) and estimation-uncertainty measures correlate better with in-task economic behavior than quantitative measures;
2. across a wide array of individual characteristics related to financial education and behavioral economics, the primary indicators of in-task performance are numeracy, adaptability, and consistency of economic decision-making; and
3. an intervention with dynamic performance-based feedback can improve performance in the Savings Game.

3. RESULTS

3.1. Subjects: Descriptive statistics

In total, 154 subjects complete the full experimental session, successfully finishing both rounds of the Savings Game. Their average age is 32.4, and 51% are female. The median subject holds a master's degree and reports being employed and earning between €1,001 and €2,000 per month as of the experimental session. Additionally, 81% report being able to save regularly with a median amount between €501 and €1,000, while 14% report having taken out some form of non-mortgage debt in the previous 12 months. 87% of subjects have a savings account (the government-regulated "Livret A"), while only 16% have a retirement plan. See Appendix B.2. Descriptive statistics for further descriptive statistics on participating subjects.

3.2. Behavior in the Savings Game

As can be seen in Figure 11 and Figure 12, average performance is well below the maximum, similar to our previous experiment. Overall, the average performance also does not improve drastically between the two rounds of the Savings Game when taken across all treatment groups together. On average, subject’s save 54% of the maximum possible per the “best” strategy in round 1 and 58% in round 2.

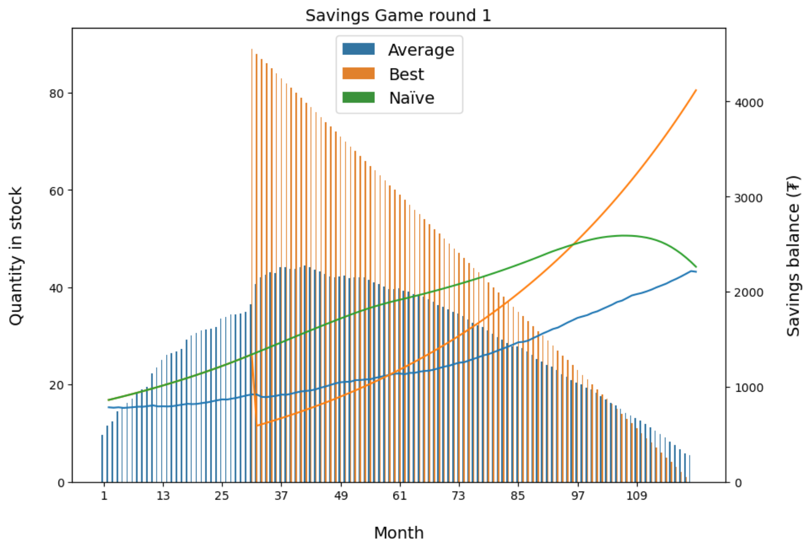

Figure 11 - Overall performance in Savings Game, round 1

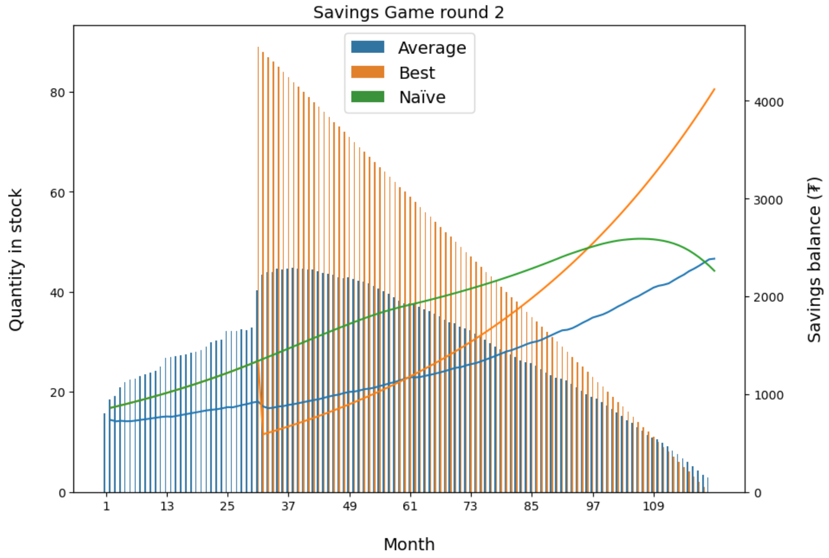

Figure 12 - Overall performance in Savings Game, round 2

3.2.1. Performance measures: Over- and wasteful-stocking and purchase adaptation

Table 18 shows the results from the first round of the Savings Game. Across all subjects, the average total savings as a percent of the maximum possible savings is 54%. Over- and wasteful-stocking account for 19% and 9% of the maximum possible performance.

Table 18 - Overall performance measures in round 1

	Mean	**Standard deviation**	**Minimum**	**50%**	**Maximum**
Total savings (%)	54	22	0	55	100
Over-stocking (%)	19	18	-1	15	72
Wasteful-stocking (%)	9	19	0	0	84
Purchase adaptation (units of good)	3.4	6.6	0.0	1.0	31.0

As can be seen in the boxplots in Figure 13, however, the mean wasteful-stocking measure is greatly skewed by outliers. Finally, average purchase adaptation, or the difference between the average quantity purchased in the three periods before and after the increase in inflation (between periods $28 \leq t \leq 30$ and $31 \leq t \leq 33$) is 3.4 units. Purchase adaptation, however, also presents significant outliers as shown in Figure 13; the median is 1 unit while the maximum is 31.[15]

[15] For comparison, the best strategy requires a purchase adaptation of 29. See 2.1.4. Performance and adaptation to changing inflation phases in Chapter 1 for further information.

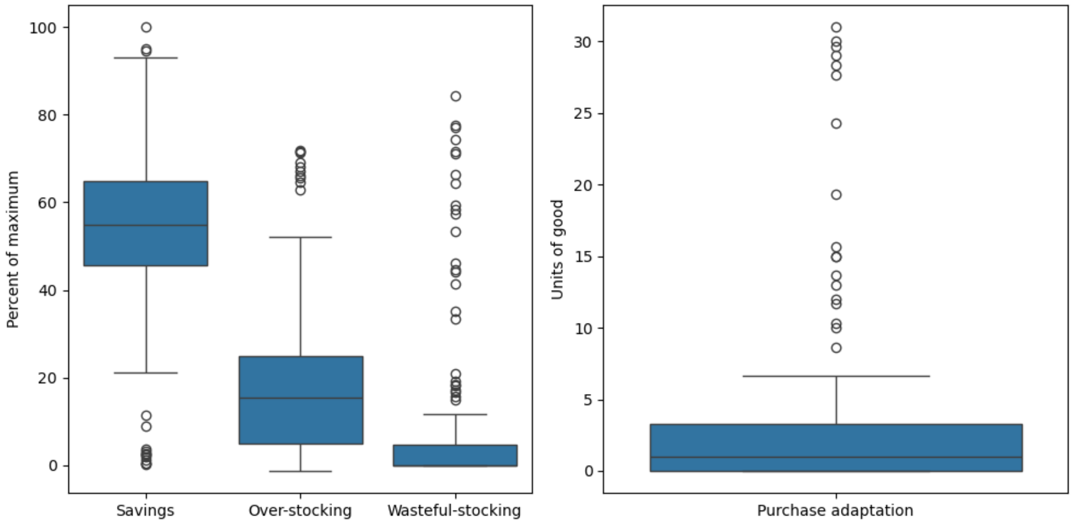

Figure 13 - Boxplot: Total savings, over-stocking, wasteful-stocking, and purchase adaptation

3.2.2. Quality of inflation expectations and perceptions and performance

We now analyze subjects' perceptions and expectations of inflation from the first round of the Savings Game.[16] As can be observed in Figure 14, subjects' perceptions and expectations of inflation generally follow actual inflation; however, their quantitative estimates are inaccurate. This pattern and discrepancy raise the possibility that subjects may have more accurate qualitative estimates than quantitative.

[16] We restrict analysis to the first round for now so as to avoid any potential learning effects impacting the results.

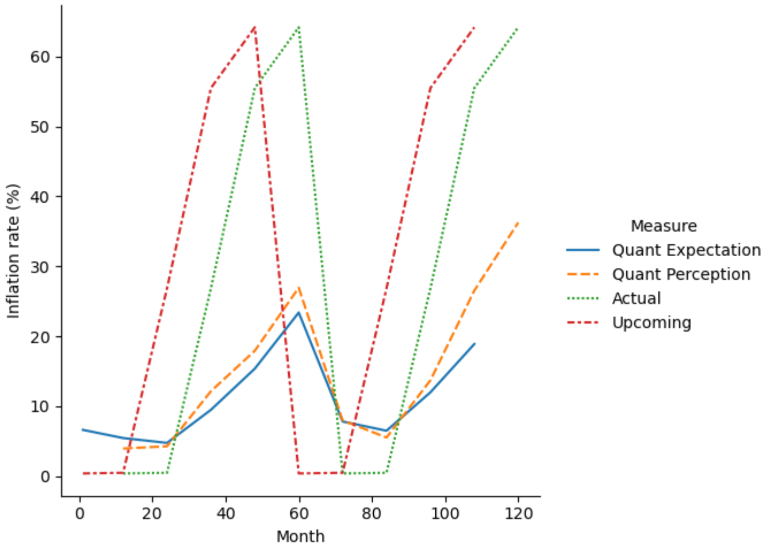

Figure 14 - Inflation in the Savings Game (round 1)

Table 19 shows the results of our inflation measures. Subjects' estimations exhibit significant biases in both low- and high-inflation phases, overestimating in low inflation and underestimating in high inflation. Their sensitivity to changes in inflation, though, is positive. Further, their qualitative estimates demonstrate greater accuracy, with subjects correctly perceiving the change in prices 78% of the time and expecting the change in prices 50%. Finally, the average subject provides uncertain estimates 41% of the time.

The qualitative results shown in Table 19 reflect subject responses converted to ordinal values as: -1, decrease; 0, stay the same; 1, slow increase; 2, moderate increase; 3, rapid increase. As such, the mean qualitative perception in low inflation of 1.24 suggests that subjects' qualitative perceptions were close, where a response of 0 ("Stayed the same") or 1 ("Increased slightly") would be considered correct, given the 12-period inflation rate in period $1 \leq t \leq 12$ is 0.38% and 0.47% in $13 \leq t \leq 24$. But, the mean being greater than 1 also implies that their qualitative perception was nonetheless biased upward. In high inflation, for which a response of 2 ("Increased moderately") or 3 ("Increased rapidly") is correct, we see that subjects' mean qualitative perception increases to 2.47, implying quite accurate qualitative perception. On the other hand, the average qualitative expectations in low and high inflation of 1.77 and 1.85

demonstrate the subjects essentially did not adjust their expectations. The average qualitative expectation being between 1 (“They will increase slowly”) and 2 (“They will increase moderately”) we might interpret as reflecting a general pessimism about future inflation but also uncertainty since between “slowly” and “moderately” may also be the least definitive of the answer options.

Table 19 - Descriptive statistics of inflation-internalization measures

	Mean	**Standard deviation**	**Minimum**	**50%**	**Maximum**
Qualitative perception, low inflation	1.24	0.64	0.00	1.25	3.00
Qualitative perception, high inflation	2.47	0.66	-1.00	2.67	3.00
Qualitative expectation, low inflation	1.77	0.66	-0.80	1.80	3.00
Qualitative expectation, high inflation	1.85	0.79	-1.00	1.80	3.00
Avg. qualitative perception accuracy	0.78	0.20	0.00	0.80	1.00
Avg. qualitative expectation accuracy	0.50	0.14	0.10	0.50	0.80
Average uncertain expectation	0.41	0.25	0.00	0.41	0.91
Perception bias, high inflation	-26.39	15.97	-49.84	-28.34	26.16
Perception bias, low inflation	4.97	8.92	-0.42	1.58	68.08
Perception sensitivity	0.57	0.39	-0.59	0.70	1.00
Expectation bias, high inflation	-32.17	15.46	-63.94	-37.74	22.06
Expectation bias, low inflation	-4.78	8.49	-14.58	-7.50	49.20
Expectation sensitivity	0.15	0.33	-0.56	0.19	0.79

Appendix B Table 2 in Appendix B.3. Results of inflation measures shows a correlation matrix of the inflation measures. We find that perception and expectation sensitivity correlated positively with final savings ($p \leq 0.01$, $p \leq 0.01$ respectively). Perception and expectation biases in low-inflation phases correlate negatively with final savings ($p \leq 0.01$, $p \leq 0.1$). Interestingly, high-inflation perception and expectation biases correlate positively with performance ($p \leq 0.1$, $p \leq 0.01$ respectively). This makes intuitive sense since an overestimation of inflation in a high-inflation phase implies a greater sense of urgency to stock up, whereas as overestimation—and therefore urgency to stock up—in low inflation would produce an opportunity cost from over-stocking.

In terms of purchase adaptation (as percentage of cumulative quantity purchased), perception and expectation biases (in high-inflation) correlate positively with an increase in purchases ($p \leq 0.05$, $p \leq 0.01$ respectively). Expectation sensitivity also correlates positively with an increase in purchases ($p \leq 0.05$). Both of these correlations are consistent with the positive correlations between high-inflation biases and performance.

Subjects' qualitative perceptions in low inflation correlate negatively with final savings ($p \leq 0.01$), while expectations do not correlate statically significantly. Their qualitative perceptions as well as expectations in high-inflation phases correlate positively with final savings ($p \leq 0.01$, $p \leq 0.05$ respectively). These results as well are consistent with the previously mentioned correlations with performance and purchase adaptation.

Further, our measures of average accuracy of qualitative perception and expectation estimates correlate positively with final savings ($p \leq 0.01$, $p \leq 0.01$ respectively); however, average uncertainty demonstrates no correlation with performance. See Appendix B Table 2 in Appendix B.3. Results of inflation measures for the complete data.

Overall, these results do reinforce the positive relationship between subjects' accurate perceptions and expectations of inflation and performance first identified in Chapter 1, extending our understanding to qualitative internalizations of inflation as well. In particular, we validate that both the qualitative and quantitative measures typically employed in survey methods do demonstrate strong correlations with behavior.

3.2.3. Real life vs. savings game: Comparison to trends from surveys in real life

Numerous analyses of household surveys on inflation perceptions and expectations demonstrate a positive relationship both between actual (i.e. headline) inflation and perceptions and expectations as well as between perceptions and expectations themselves (Bignon & Gautier, 2022; Reiche & Meyler, 2022; Weber, Gorodnichenko, et al., 2023). We observe similar trends in our experimental data too.

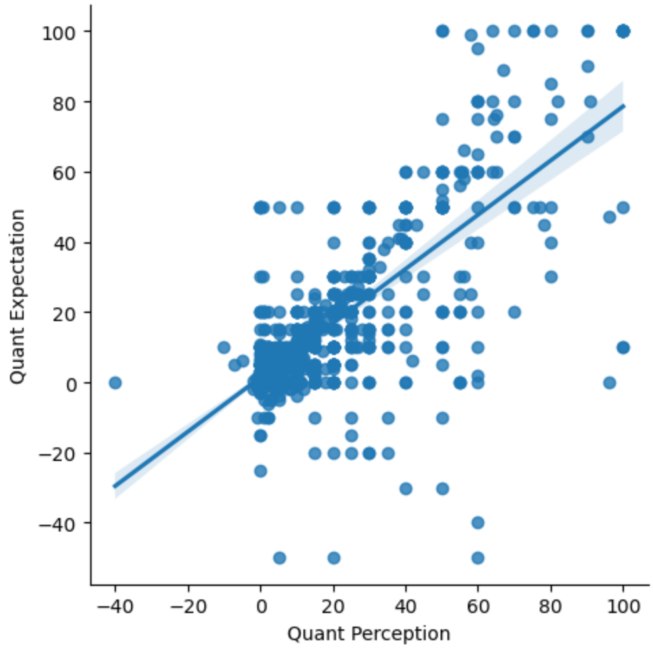

Figure 15 - Correlation between subjects' quantitative estimates of perceived and expected inflation

Firstly, like Weber et al. (2023) and Bignon and Gautier (2022), we find a clear positive correlation between quantitative perceptions and expectations ($p \leq 0.01$), as shown in Figure 15 and Table 20, as well as between qualitative perceptions and expectations ($p \leq 0.01$). These correlations may suggest that subjects report the same estimation for both or that they simply expect a continuation of the inflation they perceive at that time, another common pattern in real-life data (Ranyard et al., 2008). Generally speaking, though, these correlation provide evidence that subjects form expectations adaptively, rather than rationally (Rocheteau, 2023).

We also find positive correlations between actual inflation and quantitative both perceptions ($p < 0.01$) and expectations ($p \leq 0.01$). Similar to the observation by Weber et al. (2023) regarding real-life survey data, the correlation between quantitative perceptions and expectations is in fact stronger than the respective correlations with actual inflation. That said, however, of the qualitative measures, only perceptions demonstrate a (positive) correlation with actual inflation ($p \leq 0.01$). This nuance might offer further evidence that, at least qualitative, subjects base inflation expectations primarily on their present perceptions, anticipating a continuation of the conditions they currently perceive.

Table 20 - Correlation matrix: Estimates of perceived and expected inflation and actual inflation

	Actual	**Upcoming**	**Quantitative perception**	**Quantitative expectation**	**Qualitative perception**	**Qualitative expectation**
Actual	—					
Upcoming	0.43***	—				
Quantitative perception	0.46***	0.15***	—			
Quantitative expectation	0.31***	0.09***	0.77***	—		
Qualitative perception	0.54***	0.34***	0.52***	0.38***	—	
Qualitative expectation	0.03	-0.01	0.11***	0.41***	0.28***	—

Weber et al. (2023) further note that during the height of the COVID-19 pandemic, the dispersion of quantitative perception and expectation estimates increased. As can be seen in Figure 16, a similar pattern arises between low- and high-inflation phases, with the distribution of orange bars (estimates in high inflation) much wider than the blue bars (estimates in low inflation) widening greatly during high-inflation phases Appendix B Table 3 in Appendix B.3. Results of inflation measures confirms this; the standard deviation of quantitative perception and expectation estimates increases from 11.66 to 23.85 and 12.60 to 21.84 respectively between the low and high inflation phases. This doubling of standard deviations is in-line with the doubling observed by Weber et al. (2023). We interpret this parallel as the effect of increased economic turmoil and, thus, uncertainty.[17] Further, Gautier and Montornès (2022) find a spike in inflation-expectation uncertainty in during the first quarantine period in France.

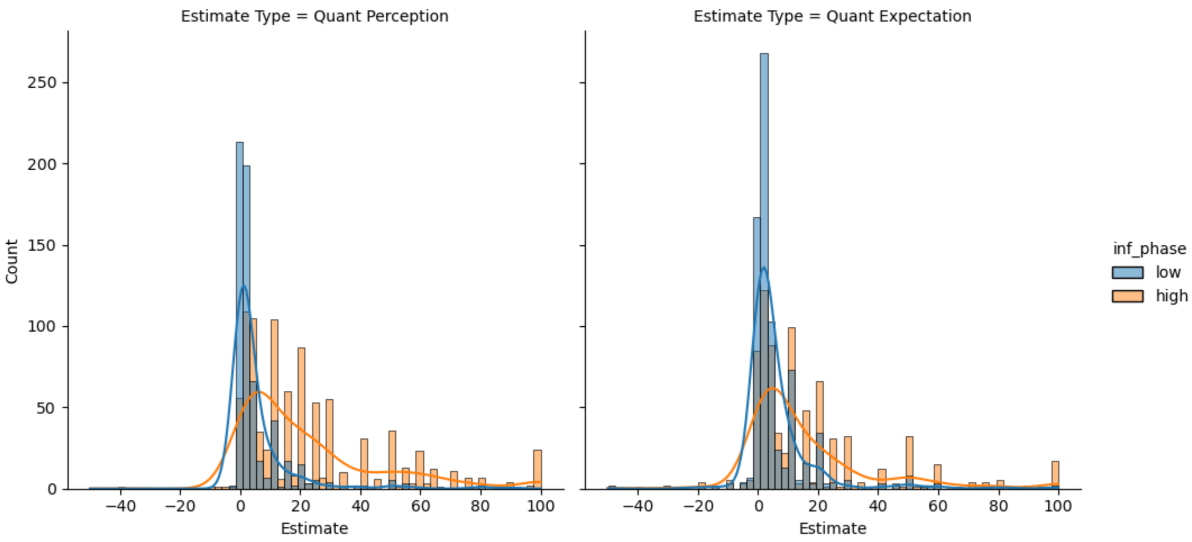

Figure 16 - Distribution of quantitative inflation estimates

To further investigate this possible relationship between uncertainty and turmoil (i.e. high-inflation phases in the Savings Game), we compare the share of uncertain responses over time. We graph the time series of actual and quantitative expected inflation with the share of uncertain responses in Figure 17. There are clear spikes in the share of uncertain estimates during high-inflation phases, rising from roughly a quarter of subjects to over half. This rise in uncertainty also confirms that estimating the inflation rate in high-inflation phases, where the 12-month rate ranges from 26.85% to 64.18%, is more difficult.

[17] Weber et al. (2023) do not directly link the onset of the COVID-19 pandemic in 2020 to "economic turmoil" or uncertainty; rather, they question whether the increased dispersion may arise from households perceiving higher inflation at that time. Considering CPI inflation did not rise until 2021, however, we consider the onset of the COVID-19 pandemic as a source of turmoil and, therefore, uncertainty.

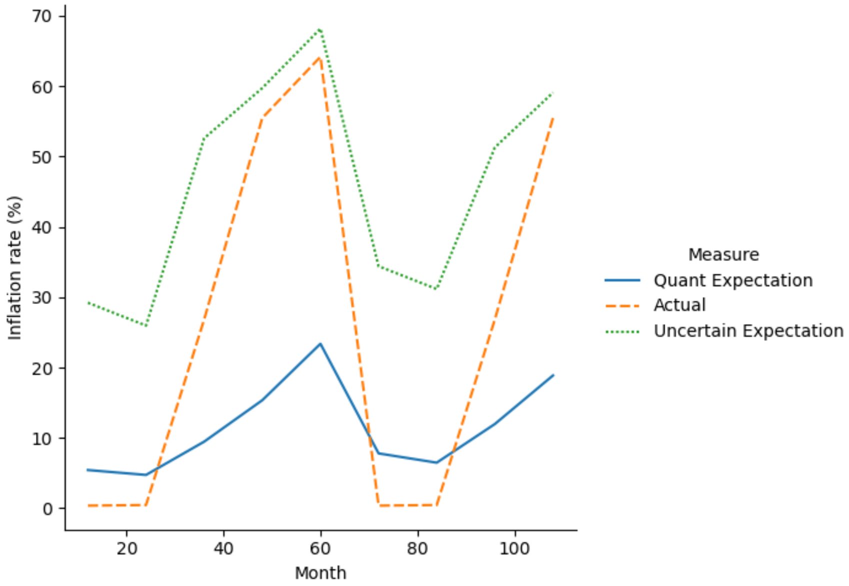

Figure 17 - Change in uncertainty of quantitative inflation expectations

Finally, we analyze the qualitative perceptions and estimations. As Andrade et al. (2023) observe, individuals' qualitative estimates are often more accurate than their quantitative ones. As shown in Figure 18, between low- and high-inflation phases, there are clear shifts to higher qualitative estimates in high-inflation phases. Additionally, as noted above, the average qualitative perception and expectation accuracy is 78% and 50%, which is markedly better than the 0.57 and 0.15 perception and expectation sensitivities from quantitative estimates.

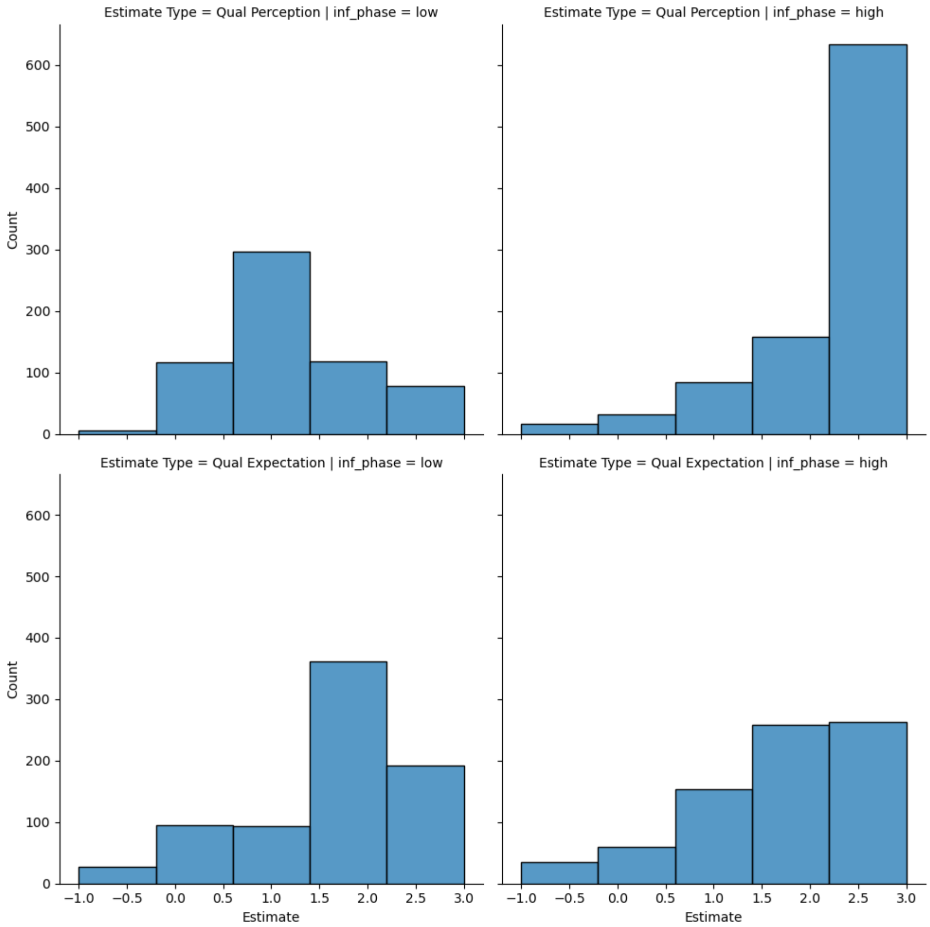

Figure 18 - Distribution of qualitative estimates of perceived and expected inflation in low- and high-inflation phases

3.2.4. Regression Analysis

3.2.4.1. Overall performance

We analyze the relationship between our performance measures (final savings, over-stocking, and wasteful-stocking as a percentage of the maximum) and inflation measures. Our objective is to assess and compare the explanatory power of the survey-elicited quantitative inflation measures to that of the qualitative inflation and uncertainty measures. We conduct three series of ordinary least squares (OLS) regressions, one for each performance measure, on the different types of inflation measures (i.e. quantitative versus qualitative and uncertainty) to compare which relate better to performance.

For our quantitative model, we repeat the OLS regressions on the original inflation measures from the previous experiment from Chapter 1: expectation sensitivity, perception sensitivity, expectation bias, and perception bias.

Table 21 shows the results for this benchmark model; Appendix B Table 4 in Appendix B.4. Supplemental results from previous experiment shows the results of the same model applied to the 4x30 inflation sequence from the previous experiment. We first note that as in the previous experiment, perception sensitivity demonstrates a positive relationship with final savings ($p < 0.01$ for both experiments) and negative relationship with wasteful-stocking ($p < 0.01$ for both experiments). Additionally, expectation sensitivity shows a positive relationship with final savings ($p \leq 0.05$) and negative relationship with over-stocking ($p \leq 0.1$). In the previous experiment, expectation sensitivity only showed a relationship with wasteful-stocking, which was positive ($p \leq 0.05$).

Table 21 - OLS regressions: Overall performance measures on inflation measures

Variables	**(1)** **Final savings (%)**	**(2)** **Over-stocking (%)**	**(3)** **Wasteful-stocking (%)**
Intercept	0.4721***	0.1847***	0.1772***
	(0.0458)	(0.0400)	(0.0416)
Expectation sensitivity	0.1204**	-0.0858*	-0.0532
	(0.0548)	(0.0478)	(0.0498)
Expectation bias	0.0045	-0.0014	-0.0022
	(0.0029)	(0.0025)	(0.0026)
Perception sensitivity	0.1336***	0.0233	-0.1233***
	(0.0479)	(0.0418)	(0.0435)
Perception bias	-0.0039	0.0015	0.0036
	(0.0027)	(0.0023)	(0.0024)
R-squared	0.1253	0.0239	0.0827
R-squared Adj.	0.1018	-0.0023	0.0581

Standard errors in parentheses.

* p<.1, ** p<.05, *** p<.01

In comparison, we repeat the three OLS regressions of performance measures, replacing the quantitative measures with the qualitative and uncertainty measures. Table 22 shows the results. Average qualitative expectation and perception accuracies each demonstrate positive relationships with final savings ($p \leq 0.01$, $p \leq 0.01$). They also both exhibit negative relationships with wasteful-stocking ($p \leq 0.1$, $p < 0.01$). Conversely, average expectation uncertainty demonstrates a negative relationship with final savings ($p \leq 0.05$) and positive relationship with wasteful-stocking ($p \leq 0.01$). We note that while the r^2 coefficients for over-stocking is lower with qualitative and uncertainty measures, the models for final savings and wasteful-stocking produce r^2 that are much higher, suggesting these measures do indeed provide greater explanatory power.

Table 22 - OLS regressions: Overall performance measures on qualitative inflation measures

Variables	**(1)** **Final savings (%)**	**(2)** **Over-stocking (%)**	**(3)** **Wasteful-stocking (%)**
Intercept	0.0856	0.2806***	0.4202***
	(0.0805)	(0.0739)	(0.0725)
Average qualitative expectation accuracy	0.3655***	-0.0815	-0.1826*
	(0.1117)	(0.1025)	(0.1006)
Average qualitative perception accuracy	0.4129***	-0.0915	-0.3883***
	(0.0838)	(0.0769)	(0.0754)
Average expectation uncertainty	-0.1353**	0.0560	0.1611***
	(0.0658)	(0.0604)	(0.0592)
R-squared	0.2024	0.0163	0.1796
R-squared Adj.	0.1865	-0.0034	0.1632

Standard errors in parentheses.

* p<.1, ** p<.05, *** p<.01

3.2.4.2. Purchase adaptation

Considering subjects' purchase adaptation—i.e. quick reaction to the increase in inflation by stocking up—is a key behavior for achieving a high final savings, we further analyze the potential contributing factors. We conduct an OLS regression of the average quantity purchased each month during a given 12-month interval on the quantitative and qualitative perceived and expected inflation, estimation uncertainty, and realized inflation. We treat the qualitative estimates as dummy variables, when subjects indicated they perceived or expected an increase in prices or not. Uncertainty is also treated as a dummy variable for the expectation estimate given in each interval.

Table 23 shows the results of the OLS. In the first interval, $1 \leq t \leq 12$, qualitative expectations and actual inflation increase the average quantity purchased ($p < 0.1$ and $p < 0.01$ respectively). As such, a subject with a qualitative expectation of high inflation as of period $t = 1$ purchases an additional 1.2 units of the good per period on average, leading to over 14 over-stocked units within 12 periods.

In the interval $12 < t \leq 24$, quantitative perceptions have a positive coefficient, albeit small ($p < 0.1$). In $24 < t \leq 36$, the reported quantitative expected inflation for the interval appears to have a surprisingly negative effect on the average quantity ($p < 0.1$). This coefficient suggests that those providing higher quantitative expected inflation estimates at $t = 24$ purchased less in the ensuing 12 months. One possible explanation for this negative relationship is that such subjects stocked up prior to the start of the third interval at $t = 25$. In fact, the positive relationship between quantitative perceptions and the average quantity in the interval $12 < t \leq 24$ offers support for this since the perception reported in this interval is at period $t = 24$ as well. In other words, considering the strong positive correlation between quantitative perceptions and expectations, if a subject reports a high perception estimate at $t = 24$, they are likely to not only stock up in the interval $12 < t \leq 24$, but report a high expectation at $t = 24$ as well. Having stocked up in $12 < t \leq 24$, though, they may not need to purchase units of the good in in the interval $24 < t \leq 36$.

Table 23 - OLS regressions: Average quantity purchased in given period

Variables	(1) Month 12	(2) Month 24	(3) Month 36	(4) Month 48
Intercept	1.8932***	0.5859	0.0017	0.0002
	(0.7165)	(0.6566)	(0.0011)	(0.0001)
Current qualitative perceptions, Increase	-0.4639	0.2097	-0.3204	0.0441
	(0.5907)	(0.6453)	(0.8605)	(0.4030)
Previous qualitative expectations, Increase	1.1989*	0.6865	1.0219	0.4129
	(0.7118)	(0.5375)	(0.6732)	(0.3188)
Uncertainty, Uncertain estimate	0.1412	0.0512	-0.0730	-0.2091
	(0.5324)	(0.3619)	(0.3856)	(0.2066)
Actual inflation	0.7194***	0.2754	0.0446	0.0095
	(0.2723)	(0.3086)	(0.0300)	(0.0070)
Current quantitative perceptions	0.0234	0.0633*	0.0276	0.0077
	(0.0288)	(0.0343)	(0.0182)	(0.0056)
Previous quantitative expectations	-0.0067	-0.0212	-0.0347*	-0.0034
	(0.0215)	(0.0252)	(0.0193)	(0.0090)
R-squared	0.0266	0.0458	0.0427	0.0279
R-squared Adj.	-0.0065	0.0136	0.0099	-0.0054

Standard errors in parentheses.

* p<.1, ** p<.05, *** p<.01

3.3. The role of individual characteristics and behavior

Across subjects, we find that 51% are financially literate, 30% are numerate, and 47% are capable of compound interest calculations as shown in Appendix B Table 6 in Appendix B.5. Results of individual characteristic measures. Appendix B Table 7 in Appendix B.5. Results of individual characteristic measures shows results from the economic preference tasks.

3.3.1. Correlations with task performance

We first correlate the measures of individual characteristics to measures from the Savings Game. We apply a Bonferroni correction to account for the interdependence of the in-task measures.

Appendix B Table 8 in Appendix B.5. Results of individual characteristic measures shows the statistically significant point bi-serial correlations between our knowledge measures (financial literacy, numeracy, and compound-interest capability) and in-task performance measures (final savings, over-stocking, wasteful-stocking, and purchase adaptation). All knowledge measures demonstrate positive correlations with final savings. Financial literacy and compound-interest capability correlate negatively with wasteful-stocking, and numeracy and compound-interest capability correlate positively with purchase adaptation.

Appendix B Table 9 Appendix B.5. Results of individual characteristic measures shows the statistically significant Pearson correlations between our economic preference measures and in-task performance measures. We find that risk aversion and time preference switches correlate negatively with final savings and positively with wasteful-stocking. Conversely, the number of correct choices from the Wisconsin card sorting task (WCST)—an indicator of adaptability—correlate positively with final savings and negatively with wasteful-stocking. Further, the number of perseverative errors in the Wisconsin card sorting task—an indicator of an inability to adapt to a changing environment, repeating the same errors despite negative feedback—correlates negatively with final savings and positively with wasteful-stocking.

Taken together, these results indicate that subjects who are more knowledgeable, adaptable (as measured by the WCST), and consistent in their economic decisions tend to perform better in the Savings Game. Further, these results provide initial support for our Hypothesis 2, that the primary indicators of in-task performance are in fact numeracy, adaptability, and consistency of economic decision-making.

Overall, in-task inflation measures (perception and expectation bias and sensitivity) demonstrate less correlation with individual characteristics. As shown in Appendix B Table 10, Appendix B Table 11, and Appendix B Table 12 in Appendix B.5. Results of individual characteristic measures, though, numeracy and number of correct choices in the Wisconsin card sorting task (i.e. adaptability) correlate positively with perception sensitivity, and time preference switches and perseverative errors correlate negatively with perception sensitivity. These correlations seem coherent. Greater perception accuracy in changing inflationary conditions requires better numerical reasoning as well as adaptability. On the other hand, those with less consistent economic preferences and/or a tendency to perseverate, continuing to commit the same errors, may be less capable of perceiving changes in inflation.

Finally, we find similar correlations between the characteristic measures and qualitative inflation measures (average qualitative perception and expectation accuracies and average expectation uncertainty). See Appendix B Table 13, Appendix B Table 14, and Appendix B Table 15 in Appendix B.5. Results of individual characteristic measures. Similar to the quantitative measures, numeracy and adaptability correlate positively with qualitative perception accuracy, and time preference switches and perseverative errors correlate negatively. Additionally, we find that the number of smaller-sooner time preference choices (i.e. a high discount rate) correlates negatively with qualitative perception accuracy as well. These results are also coherent with the underlying abilities necessary for accurate qualitative perceptions: strong numerical reasoning and adaptability.

3.3.2. Regression Analysis

To more clearly observe the interplay of individual characteristics in overall performance, we conduct OLS regressions of total savings, over-stocking, and wasteful-stocking in round 1 on the different characteristic measures, where financial literacy, numeracy, and compound interest-capability are dummy variables. Table 24 shows the results. Final savings is positively impacted by compound interest-capability ($p < 0.05$) and negatively impacted by time preference switches ($p < 0.01$). The model for over-stocking does not produce any statistically significant coefficients, but wasteful-stocking demonstrates a negative relationship with financial literacy ($p < 0.1$) and positive relationship with time preference switches ($p < 0.01$). These are coherent considering that greater knowledge should contribute to better performance measures, as opposed to less consistency in economic decisions, which contributes to lower performance.

Table 24 - OLS regressions: Performance measures on individual characteristics (round 1)

Variables	(1) Final savings (%)	(2) Over-stocking (%)	(3) Wasteful-stocking (%)
Intercept	0.5618***	0.2213	-0.1049
	(0.1618)	(0.1563)	(0.1428)
Financially literate	0.0434	0.0019	-0.0606*
	(0.0348)	(0.0337)	(0.0308)
Numerate	0.0583	-0.0401	-0.0341
	(0.0376)	(0.0363)	(0.0332)
Compound interest-capable	0.0760**	-0.0288	-0.0288
	(0.0369)	(0.0356)	(0.0325)
WCST, number correct	0.0024	-0.0005	0.0014
	(0.0055)	(0.0053)	(0.0049)
WCST, set-loss errors	-0.0097	0.0002	0.0105
	(0.0090)	(0.0087)	(0.0079)
WCST, perseverative errors	-0.0008	-0.0010	0.0056
	(0.0069)	(0.0066)	(0.0061)
Risk aversion, safe choices	0.0059	-0.0030	0.0045
	(0.0086)	(0.0083)	(0.0076)
Risk aversion, switches	-0.0133	-0.0169	0.0189
	(0.0142)	(0.0137)	(0.0125)
Loss aversion, coin tosses	-0.0072	-0.0030	0.0098
	(0.0115)	(0.0111)	(0.0102)
Loss aversion, switches	0.0288	-0.0076	-0.0291
	(0.0241)	(0.0233)	(0.0213)
Time preferences, smaller-sooner choices	-0.0055	0.0029	0.0044
	(0.0038)	(0.0037)	(0.0034)
Time preferences, switches	-0.0501***	0.0193	0.0489***
	(0.0137)	(0.0132)	(0.0121)
R-squared	0.3034	0.0479	0.3109
R-squared Adj.	0.2441	-0.0331	0.2522

Standard errors in parentheses.

* p<.1, ** p<.05, *** p<.01

3.4. Changes in performance

3.4.1. Learning effect

Table 25 shows the change in performance measures between the first and second rounds of the Savings Game. We use purchase adaptation as a percentage of the total number of units of the good purchased before period $t = 28$. This measure can be interpreted as the percentage of the total units of the good the subject needs to buy as of period $t = 28$ to survive through $t = 120$ that they buy in the interval $31 \leq t \leq 33$. This measure facilitates comparison because the amount a subject should buy in this interval depends on how much they have bought up to this point. Previously, we use the direct magnitude of purchase adaptation in terms of units of the good because it is more intuitive to interpret.

Wasteful-stocking shows the only statistically significant change ($p \leq 0.05$), decreasing. This makes sense considering it is the most obvious mistake to subjects as they see that they finish a round with stock remaining. Otherwise, we find no learning effect.

Table 25 - Change in performance between first and second round

	Session 1	**Session 2**	**Change in performance**
Final savings (%)	54	58	4
(std)	(22)	(23)	(22)
Over-stocking (%)	19	20	1
(std)	(18)	(23)	(26)
Wasteful-stocking (%)	9	5	-4**
(std)	(19)	(14)	(14)
Purchase adaptation (%)	9.38	15.37	5.99
(std)	(21.32)	(31.11)	(30.21)

3.4.2. Treatment

As Table 26 reveals, recipients of Intervention 2 improve savings, over-stocking, and purchase adaptation ($p \leq 0.05$, $p \leq 0.01$, and $p \leq 0.05$ respectively); recipients of Intervention 1 only demonstrate improve wasteful-stocking ($p \leq 0.05$). The lack of significant reduction in wasteful-stocking among the Intervention 2 group appears mainly due to the fact that its mean cost incurred was already three times less in round 1 than amongst recipients of Intervention 1.

Finally, amongst the control group, the only statistically significant changes in performance are in fact an increase in over-stocking ($p \leq 0.01$) and decrease in purchase adaptation ($p \leq 0.05$). Increased over-stocking is a natural reaction after the first session for subjects who do not properly recognize the importance of protecting purchasing power. Instead, they become more pessimistic about future inflation and simply ensure they buy as much as possible at a low price. Increased over-stocking can also reduce purchase adaptation since fewer subjects may still require buying any units of the good by $t = 31$.

Table 26 - Change in performance between sessions 1 and 2 for each treatment group

	Intervention 1	**Intervention 2**	**Control**
Final savings (%)	8	6**	-2
(std)	(21)	(21)	(23)
Over-stocking (%)	-1	-8***	15***
(std)	(2)	(25)	(26)
Wasteful-stocking (%)	-7**	-1	-6
(std)	(17)	(7)	(17)
Purchase adaptation (%)	8.99	9.63**	-0.99**
(std)	(37.19)	(32.81)	(15.88)

3.4.3. Regression analysis

3.4.3.1. Overall performance

To assess the treatments' and learning effect's impacts more directly, we conduct OLS regressions of the change in each performance measure (i.e. the difference between rounds 1 and 2) on the treatment received as dummy variables. Additionally, given the correlation between inflation measures and performance, we also regress the change in inflation measures on the treatment.

As shown in Table 27, both Intervention 1 and Intervention 2 demonstrate positive effects on final savings ($p < 0.01, p \leq 0.01$) and negative effects on over-stocking ($p <$

0.01, $p \leq 0.01$). Amongst inflation measures, Intervention 1 increases expectation sensitivity ($p \leq 0.01$), while decreasing uncertainty ($p \leq 0.1$). Conversely, Intervention 2 demonstrates no statistically significant impact on any inflation measures.

Table 27 - OLS regressions of performance and inflation measures on treatment

Variables	(1) Final savings (%)	(2) Over-stocking (%)	(3) Wasteful-stocking (%)	(4) Qualitative perception accuracy	(5) Qualitative expectation accuracy	(6) Uncertainty	(7) Perception sensitivity	(8) Perception bias	(9) Expectation sensitivity	(10) Expectation bias
Intercept	-0.1782***	0.1784***	-0.0174**	0.0020	0.1120***	0.0255	0.0868***	0.1506	0.1327***	1.8896**
	(0.0331)	(0.0271)	(0.0081)	(0.0178)	(0.0173)	(0.0275)	(0.0326)	(0.8989)	(0.0408)	(0.9199)
Intervention 1	0.2557***	-0.1969***	-0.0176	0.0393	-0.0163	-0.0768*	-0.0516	-1.2114	0.1591***	-0.5458
	(0.0478)	(0.0391)	(0.0117)	(0.0258)	(0.0250)	(0.0397)	(0.0471)	(1.2986)	(0.0589)	(1.3288)
Intervention 2	0.2929***	-0.2681***	0.0139	0.0083	-0.0154	0.0090	-0.0135	0.8255	-0.0141	0.5437
	(0.0451)	(0.0370)	(0.0111)	(0.0243)	(0.0236)	(0.0375)	(0.0445)	(1.2267)	(0.0556)	(1.2552)
R-squared	0.1356	0.1529	0.0248	0.0084	0.0019	0.0185	0.0042	0.0086	0.0343	0.0024
R-squared Adj.	0.1299	0.1473	0.0184	0.0019	-0.0047	0.0121	-0.0023	0.0021	0.0280	-0.0042

Standard errors in parentheses.

* p<.1, ** p<.05, *** p<.01

3.4.3.2. Purchase adaptation

Next, we repeat the average quantity purchased regressions initially reported in Table 23 to assess the possible impacts of a learning or treatment effect during the same four intervals as before. Table 28 shows the results.

The first interval, $1 \leq t \leq 12$ (which takes place during low inflation), is especially relevant to identifying potential learning and treatment effects because it represents the only purely independent interval. Subsequent intervals' decisions depend on purchases made previously. In the first interval, qualitative expectations and actual inflation increase the average quantity purchased ($p < 0.01$ and $p < 0.01$ respectively). There is a positive impact (i.e. negative coefficient[18]) for Intervention 2 ($p < 0.01$). The positive coefficients of the interaction terms for each intervention with the pre-treatment dummy variable ($p < 0.01$, $p \leq 0.01$) further suggest an improvement due to the

[18] A negative coefficient represents a positive impact since the average quantity per month should be one unit in the first period.

interventions since this implies that post-treatment sees a reduction in the average quantity purchased, which is strategically better. Further, the interaction term of receiving Intervention 1 and quantitative expectations is positive ($p \leq 0.05$), which suggests that Intervention 1 recipients that had overly pessimistic expectations about inflation did at least make an appropriate purchase decision, given their expectations. In other words, these subjects did apply the strategy appropriately of increasing their purchases when they expect higher inflation; they just were misguided in their expectations. That said, we also observe a counter-productive learning effect in the first interval (i.e. negative coefficient for the pre-treatment variable, $p < 0.01$), implying the average quantity increased in round 2 across all subjects.

In the second interval, $12 < t \leq 24$ (when inflation still remains low), quantitative perceived ($p \leq 0.05$) and actual inflation ($p < 0.01$) increase the quantity purchased. There is also a positive interaction term between Intervention 1 and qualitative perceptions ($p \leq 0.1$).

The third interval, $24 < t \leq 36$ (the first interval with high inflation), is positively impacted by the interaction of Intervention 2 and the pre-treatment dummy variable (i.e. negative coefficient, $p < 0.1$), actual inflation ($p < 0.1$), and quantitative perceived inflation ($p < 0.1$).

Finally, the fourth interval, $36 < t \leq 48$ (high inflation), exhibits a positive coefficient for the pre-treatment variable ($p < 0.05$), suggesting that subjects purchased less in round 2, which is coherent with the negative interaction term for Intervention 2 and pre-treatment ($p < 0.01$) since subjects would have stocked up in the previous interval(s) and not needed to make any purchases in the fourth. Qualitative perceptions have a relatively strong negative impact ($p \leq 0.01$), while its interaction term with both interventions is positive ($p \leq 0.05$ for both) as well as for Intervention 2 and quantitative perceptions ($p \leq 0.1$), suggesting positive impact from the interventions. Qualitative expectations exhibit a positive effect ($p \leq 0.1$). Additionally, actual inflation has a slight positive impact on the average quantity in the fourth interval ($p < 0.01$).

Overall, these results do suggest that both interventions alter and strengthen the factors relating to the average quantities purchased during these intervals, particularly the first interval, adding greater power to subjects' perceptions and expectations and in-line with the overall improvements in performance observed as well.

Table 28 - OLS regressions: Average quantity purchased on treatment effects

Variables	(1) Month 12	(2) Month 24	(3) Month 36	(4) Month 48
Intercept	3.5888***	1.5329***	0.0028*	0.0005***
	(0.6509)	(0.4868)	(0.0016)	(0.0002)
Treatment, Intervention 1	-1.6176	-0.9973	-1.8579	-0.3438
	(1.3301)	(0.8887)	(1.7683)	(0.9351)
Treatment, Intervention 2	-3.2086***	-1.1124	1.0499	-1.0797
	(1.1052)	(0.7307)	(1.4632)	(0.7552)
Round, Pre-treatment	-1.9799***	0.2098	0.2580	0.5769**
	(0.5369)	(0.3119)	(0.4506)	(0.2268)
Uncertainty, Uncertain estimate	-0.2670	-0.2132	-0.1481	-0.0262
	(0.6177)	(0.3742)	(0.5270)	(0.2672)
Current qualitative perceptions, Increase	-0.8970	-0.7867	-0.5858	-1.5895***
	(0.7049)	(0.4799)	(1.1838)	(0.6004)
Previous qualitative expectations, Increase	1.9553***	0.1534	-0.5579	0.7199*
	(0.7205)	(0.5399)	(0.7435)	(0.4261)
Treatment, Intervention 1 × Round, Pre-treatment	2.3099***	-0.2216	-0.5687	-0.3893
	(0.7660)	(0.4590)	(0.6469)	(0.3329)
Treatment, Intervention 2 × Round, Pre-treatment	2.9121***	0.2618	-1.0285*	-0.8193***
	(0.7251)	(0.4325)	(0.6138)	(0.3036)
Treatment, Intervention 1 × Uncertainty, Uncertain estimate	-0.2544	0.8249	0.5699	-0.3792
	(0.8891)	(0.5223)	(0.7616)	(0.3778)
Treatment, Intervention 2 × Uncertainty, Uncertain estimate	0.8666	0.4242	0.0263	0.1694
	(0.8783)	(0.5382)	(0.7438)	(0.3680)
Treatment, Intervention 1 × Current qualitative perceptions, Increase	0.1250	1.2893*	2.0848	1.7909**
	(1.0524)	(0.7220)	(1.6834)	(0.8754)
Treatment, Intervention 2 × Current qualitative perceptions, Increase	0.9820	0.7064	-0.5199	1.6919**
	(0.9072)	(0.6207)	(1.5384)	(0.8128)
Treatment, Intervention 1 × Previous qualitative expectations, Increase	-1.8182	-0.0003	1.3834	-1.1897
	(1.2197)	(0.8650)	(1.2803)	(0.7229)
Treatment, Intervention 2 × Previous qualitative expectations, Increase	-1.0567	0.2546	1.3198	-0.4570
	(1.0391)	(0.7054)	(1.0397)	(0.6405)
Actual inflation	1.3637***	0.7205***	0.0743*	0.0281***
	(0.2474)	(0.2288)	(0.0433)	(0.0104)
Current quantitative perceptions	-0.0309	0.0823**	0.0442*	0.0005
	(0.0639)	(0.0378)	(0.0267)	(0.0076)
Treatment, Intervention 1 × Current quantitative perceptions	0.0561	-0.0239	-0.0376	0.0012
	(0.0679)	(0.0465)	(0.0395)	(0.0102)
Treatment, Intervention 2 × Current quantitative perceptions	0.1279	-0.0539	-0.0046	0.0164*
	(0.0885)	(0.0480)	(0.0377)	(0.0094)
Previous quantitative expectations	-0.0128	-0.0018	-0.0156	-0.0081
	(0.0230)	(0.0339)	(0.0305)	(0.0127)
Treatment, Intervention 1 × Previous quantitative expectations	0.0838*	-0.0131	-0.0207	0.0084
	(0.0426)	(0.0441)	(0.0401)	(0.0162)
Treatment, Intervention 2 × Previous quantitative expectations	0.0356	-0.0354	-0.0348	-0.0083
	(0.0322)	(0.0445)	(0.0418)	(0.0160)
R-squared	0.1793	0.1284	0.1023	0.1064
R-squared Adj.	0.1219	0.0674	0.0393	0.0430

Standard errors in parentheses.
* p<.1, ** p<.05, *** p<.01

3.4.3.3. Individual characteristics

We then analyze the relationship between treatment and individual characteristics through OLS regressions of the change in performance from round 1 to 2, measuring the interaction terms between each treatment and the characteristic measures. While overall not statistically significant, there are a few notable results. Table 29 shows abbreviated results with statistically significant relationships.

The results demonstrate that the interaction term of Intervention 1 and set-loss errors has a negative impact on final savings ($p < 0.05$). This may suggest that those who do not properly maintain behaviors after feedback do not benefit from, or are even misguided by, the feedback of Intervention 1.

The interaction term of risk aversion safe choices and Intervention 1 produces more wasteful-stocking ($p \leq 0.01$). Conversely, the interaction term of control and risk aversion switches is positive ($p < 0.05$) for final savings and negative for over-stocking ($p \leq 0.05$). At first glance, this is a surprising result; however, risk aversion switches correlate strongly with wasteful-stocking at baseline. As a result, the improvement may arise from the across-the-board learning effect, reducing excess quantities purchased in round 1 and leading to higher final savings in round 2.

Interaction terms are positive ($p \leq 0.01$) and negative ($p \leq 0.05$) between loss aversion switches and control and Intervention 1 respectively for wasteful-stocking. Finally, Intervention 1 has a positive interaction term with time preference smaller-sooner choices and final savings ($p \leq 0.01$) and negative terms with over- ($p \leq 0.1$) and wasteful-stocking ($p \leq 0.05$), while the control has a negative interaction term with final savings ($p \leq 0.1$). This suggests that more present-focused subjects improve their performance with Intervention 1.

For the complete results, see Appendix B Table 16 in Appendix B.6. Ordinary least squares regression of individual characteristics and treatment.

Table 29 - OLS regressions: Change in performance on treatment and individual characteristics (abbreviated results)

Variables	(1) Final savings (%)	(2) Over-stocking (%)	(3) Wasteful-stocking (%)
Treatment, Control × WCST, set-loss errors	-0.0110	0.0147	-0.0032
	(0.0266)	(0.0219)	(0.0061)
Treatment, Intervention 1 × WCST, set-loss errors	-0.0711**	0.0372	0.0099
	(0.0313)	(0.0258)	(0.0072)
Treatment, Intervention 2 × WCST, set-loss errors	-0.0027	-0.0104	0.0027
	(0.0250)	(0.0207)	(0.0057)
Treatment, Control × Risk aversion, safe choices	0.0217	-0.0218	0.0043
	(0.0291)	(0.0240)	(0.0067)
Treatment, Intervention 1 × Risk aversion, safe choices	0.0109	-0.0356	0.0196***
	(0.0274)	(0.0226)	(0.0063)
Treatment, Intervention 2 × Risk aversion, safe choices	-0.0120	0.0178	-0.0027
	(0.0278)	(0.0229)	(0.0064)
Treatment, Control × Risk aversion, switches	0.0949**	-0.0985**	0.0109
	(0.0479)	(0.0395)	(0.0110)
Treatment, Intervention 1 × Risk aversion, switches	-0.0625	0.0465	0.0068
	(0.0512)	(0.0422)	(0.0117)
Treatment, Intervention 2 × Risk aversion, switches	-0.0441	0.0444	-0.0057
	(0.0506)	(0.0417)	(0.0116)
Treatment, Control × Loss aversion, switches	0.0371	-0.0795	0.0426***
	(0.0643)	(0.0531)	(0.0147)
Treatment, Intervention 1 × Loss aversion, switches	0.0753	-0.0086	-0.0436**
	(0.0927)	(0.0765)	(0.0212)
Treatment, Intervention 2 × Loss aversion, switches	0.0359	0.0083	-0.0097
	(0.0938)	(0.0774)	(0.0215)
Treatment, Control × Time preferences, smaller-sooner choices	-0.0231*	0.0165	-0.0004
	(0.0135)	(0.0112)	(0.0031)
Treatment, Intervention 1 × Time preferences, smaller-sooner choices	0.0407***	-0.0197*	-0.0079**
	(0.0142)	(0.0118)	(0.0033)
Treatment, Intervention 2 × Time preferences, smaller-sooner choices	-0.0069	0.0035	0.0019
	(0.0105)	(0.0087)	(0.0024)
R-squared	0.3064	0.3109	0.3185
R-squared Adj.	0.0930	0.0989	0.1088

Standard errors in parentheses.

* p<.1, ** p<.05, *** p<.01

3.4.3.4. Mediation analysis

Finally, we conduct a mediation analysis of the treatments to assess whether any of the impact from the intervention was through a mediator variable related to inflation. For each treatment, we conduct a mediation analysis of the change in overall performance with the changes in: average qualitative perceptions, average qualitative expectations, average uncertainty, perception sensitivity, perception bias, expectation sensitivity, and expectation bias. Table 30 and Table 31 show the statistically significant results.

Intervention 1 demonstrates a mediation path ($p \leq 0.05$), whereby the treatment reduces uncertainty, which in turn improves performance. Intervention 2, however, demonstrates strictly a direct effect between the treatment and performance change outcome. As a result, we find that for Intervention 1, the change in inflation estimation uncertainty is a mediator. Further, this effect represents a full mediation ($p < 0.05$). Intervention 2, however, demonstrates a direct effect on the change in performance rather than mediation.

See Appendix B.7. Mediation analysis results for the full results.

Table 30 - Mediation analysis of Intervention 1 (abbreviated results)

Path	Coefficient	STE	p value
Change in average expectation uncertainty ~ Intervention 1	-0.08	0.03	0.02
Change in expectation sensitivity ~ Intervention 1	0.17	0.05	0.00
Change in final savings ~ Change in average expectation uncertainty	-0.30	0.08	0.00
Total	0.10	0.04	0.03
Direct	0.07	0.05	0.14
Indirect Change in average uncertainty	0.02	0.01	0.02

Table 31 - Mediation analysis of Intervention 2 (abbreviated results)

Path	Coefficient	STE	p value
Change in expectation sensitivity ~ Intervention 2	-0.09	0.05	0.06
Change in final savings ~ Change in average expectation uncertainty	-0.30	0.08	0.00
Total	0.17	0.04	0.00
Direct	0.20	0.04	0.00

4. DISCUSSION

Considering the results described above, we first remark how these results bolster those of the previous experiment. See Section 3. Results of Chapter 1. Comparing the present results to the results of the previous experiment’s 4x30 sequence, we observe that final savings, over-stocking, and wasteful-stocking as a percentage of the maximum possible final savings all fall well within a standard deviation: 54% versus 48%, 19% versus 31%, and 9% versus 9% for the present and previous experiment respectively. The quantitative inflation sensitivity measures are quite similar (0.15 versus 0.12 and 0.57 versus 0.59 for expectations and perceptions in the present and previous experiment's 4x30 sequence respectively). We find similar correlations between the two experiments' 4x30 sequences for final savings and: perception bias in low inflation, perception sensitivity, and expectation bias in low inflation. For purchase adaptation, we find similar correlations for: perception bias in high inflation, expectation bias in high inflation, and expectation sensitivity. See Appendix B Table 5 in Appendix B.4. Supplemental results from previous experiment for all correlations from the previous experiment for the 4x30 sequence.

Additionally, the correlations between individual characteristics on the one hand and performance and inflation estimate measures on the other hand are generally similar too. In particular, the relationships between numerical abilities (i.e. numeracy and compound interest-capability) and performance as well as between consistency of economic decisions (i.e. number of switches) and performance are quite evident from both experiments. The results in our previous experiment regarding adaptability lack power to draw a firm conclusion on the characteristic's relation to Savings-Game performance. With a 48% larger sample size in the present study, we see much clearer positive correlations between performance and adaptability as well as negative correlation with perseverative errors.

The regressions of overall performance measures demonstrate the same relationships for perception sensitivity (see Table 21 and Table 22 as well as Appendix B Table 4 in Appendix B.4. Supplemental results from previous experiment). Qualitative perception accuracy also exhibits a very strong and positive relationship ($p \leq 0.01$). Further, we observe other variables having statistically significant contributions to performance in this experiment. This difference may arise from the change in estimation elicitation method (slider versus survey-style) and thus precision. In fact, it is possible that the slider elicitation method acts somewhat as a hybrid between quantitative and qualitative, given the lower precision. In that case, a positive relationship with perception sensitivity in the previous experiment could be considered consistent with the positive relationship observed in the present experiment in terms of qualitative perceptions.

Similar to the previous experiment, we also observe a learning effect, although only in decreased wasteful-stocking, which is in fact the same magnitude as the previous experiment. In the previous, we observe a learning effect on final savings but not in the present experiment. Considering subjects complete twice as many rounds of the Savings Game in the previous experiment, this larger and statistically significant learning effect in the former is not surprising. Nevertheless, in the current shortened procedure, learning does seem to consistently occur between rounds. We further observe what is essentially a learning effect within the control group, whereby they increase their over-stocking cost. This too is consistent with results from the previous experiment; we consider this counter-productive learning effect a natural, pessimistic reaction to the experience of the previous round(s).

We consider the clear similarity between results of the two experiments a clear reflection of the replicability of the Savings Game. This is especially encouraging considering the critical importance of experimental replicability for scientific progress and the challenges the literature currently faces in reproducing results. In fact, a recent study of 100 psychology experiments published in the top three psychology journals manage to reproduce results simply in the same direction for 36% of all the experiments (Camerer et al., 2016). The same is true for economics. In systematically replicating 18 economics experiments from the *American Economic Review* and the *Quarterly Journal of Economics*, Camerer et al. (2016) reproduce results in the same direction as the original for 61% of the experiments (11 experiments). Overall, the results across our two experiments are consistent with the baseline replicability.

We now examine the results in regards to the hypotheses tested that:

1. individuals' inflation survey responses
    a. correlate with their in-task economic behaviors as well as that
    b. qualitative inflation-estimate (perceptions and expectations) and estimation-uncertainty measures correlate better with in-task economic behavior than quantitative measures;
2. across a wide array of individual characteristics related to financial education and behavioral economics, the primary indicators of in-task performance are numeracy, adaptability, and consistency of economic decision-making; and
3. an intervention with dynamic performance-based feedback can improve performance in the Savings Game.

4.1. Hypothesis 1

For Hypothesis 1a, the regression of subjects' average quantity purchased in given intervals on qualitative and quantitative estimations reveals some degree of decision-making predictability. We do indeed find that, of the inflation estimation variables, qualitative expectations in the first interval ($1 \leq t \leq 12$) are the strongest predictor of average quantity purchased during that interval ($p < 0.1$). In the second interval ($12 < t \leq 24$), quantitative perceptions are the strongest predictor ($p < 0.1$) as are quantitative expectations in the third interval ($p \leq 0.1$). A key challenge of assessing the relationship between decision-making and inflation internalization is that when subjects demonstrate significant over-stocking, they must ultimately purchase few quantities throughout the rest of the round of the Savings Game, limiting the degree of behavioral change for the model to explain. Nevertheless, the results provide some initial evidence that the survey responses correlate to behavior on a period-by-period basis.

The regressions of performance measures (Table 21 and Table 22) demonstrate that the measures based off subjects' survey responses correlate with their overall performance behavior. In particular, subjects who demonstrate greater expectation sensitivity save more ($p \leq 0.05$) while over-stocking less ($p \leq 0.1$). Those with greater perception sensitivity also save more ($p \leq 0.01$) while wasteful-stocking less ($p \leq 0.01$).

Alternatively, subjects who qualitatively anticipate inflation more accurately, save more ($p \leq 0.01$) and wasteful-stock less ($p \leq 0.1$), while those who qualitatively perceive inflation more accurately perform save more ($p \leq 0.01$) and wasteful-stock less ($p \leq 0.01$). Additionally, subject who exhibit greater uncertainty in their expectation estimations save less ($p \leq 0.05$) and wasteful-stock more ($p \leq 0.01$).

Moreover, regarding Hypothesis 1b, we observe that the models of qualitative and uncertainty measures provide greater explanatory power than the quantitative measures for final savings and wasteful-stocking. For over-stocking, only (quantitative) expectation sensitivity demonstrates predictive power.

Being the case, we interpret these results as a validation that inflation survey responses, and particularly measures based off of the responses, offer predictability of behavior. We additionally conclude that qualitative inflation estimates and inflation estimation uncertainty are better predictors of overall behavior than quantitative inflation estimates.

Future research with the Savings Game could aim to better understand the early over-stocking tendency and underlying pessimism about inflation, which appears at the beginning of each round of the Savings Game in both experiments. The persistent difficulty in directly linking estimations to purchase decisions that arises from severe over-stocking, though, presents a challenge to be addressed through new variations of inflation sequences and/or designs of the Savings Game.

In summary, the results provide support for Hypotheses 1a and 1b.

4.2. Hypothesis 2

Similar to our previous experiment, we do find that numerical abilities and economic-decision consistency are the primary individual characteristics that relate to stronger performance in the Savings Game. We also find evidence that adaptability is a strong indicator too. This hypothesis is validated both by the correlations between these characteristics and the in-task performance and inflation internalization measures as well as the OLS regression on individual characteristics.

Our results, therefore, also support Hypothesis 2.

4.3. Hypothesis 3

We find that both interventions have a positive impact on performance. Compared to the lack of general impact from the simple intervention in our previous experiment with no feedback, we find that performance-based feedback coupled with more pragmatic recommendations demonstrates a clear improvement on performance.

Per the difference-in-difference (Table 26) and OLS regression (Table 27) analyses, Intervention 1 demonstrates less impact on overall performance than Intervention 2; however, Intervention 1 does show positive impact on auxiliary factors: qualitative perception accuracy, expectation sensitivity, and uncertainty. We observe a similar pattern in the mediation analysis, Intervention 1 appears to produce impact by reducing the uncertainty, which subsequently improves performance. Intervention 2, on the other hand, demonstrates no mediator relationship. Rather, Intervention 2's effect on performance is direct. This is surprising considering that although both interventions explain how to estimate inflation, Intervention 2 places greater emphasis on the explanation. One possible interpretation of the lack of a mediation through decreased uncertainty may suggest that Intervention 1's simpler explanation of inflation estimation is more effective in reducing subjects' uncertainty.

Nevertheless, the more detailed process that Intervention 2 provides subjects overall—emphasizing the origin of the opportunity costs associated with each mistake—clearly has a significant direct effect on their performance. As such, we conclude that performance-based feedback is necessary to improve performance, estimation explanations should be straightforward, and the origins of opportunity costs as they relate to the possible mistakes are necessary to ensure subjects internalize an intervention's recommendations.

Our results support Hypothesis 3 as well, therefore.

4.4. General analysis

The results of the present experiment, and in fact the previous experiment as well, reinforce the difficulty that individuals face in perceiving and anticipating (i.e. internalizing) inflation. We also find reaffirming evidence that individuals' internalizations of inflation play a key role in their consumption and savings decisions. In our previous experiment in Chapter 1, we find evidence of the positive relationship between the accuracy of subjects' inflation perceptions and expectations and their performance. Our new results reinforce this relationship as well as reveal a broader connection between performance and inflation internalization, demonstrating the important role that qualitative internalizations and uncertainty play. Indeed, the stronger relationships we find between qualitative internalizations and performance suggest that compared to their quantitative percentage estimates, household consumers' intuitions on inflation may be both more accurate reflections of the inflation they perceive and expect as well as a better predictor of their behavior.

Reinforcing the relationship between how individuals internalize inflation and ultimately make decisions, therefore, also underscores the importance of providing them sufficient information to better perceive and anticipate inflation. This may be especially important considering the adaptive, rather than rational, expectations they demonstrate (Rocheteau, 2023). As our interventions suggest, ensuring individuals understand inflation's impact on purchasing power and the real interest rate facilitates better decision-making. Thus, communication from central banks on inflation is clearly important, and tools such as simulators of personal inflation rates based on individuals' unique consumption basket are helpful. Being so, communication and information on the real interest rate is, nonetheless, rarely discussed or readily made available for household consumers. Indeed, although governments, banks, and the press communicated the increase in nominal interest rates on savings accounts during the most recent rise in inflation in developed economies, knowing the real interest rate, which remained negative, required households to personally calculate it.

Additionally, the replicability that we demonstrate between the previous experiment in Chapter 1 and the present is encouraging. As alluded to above, the replicability challenge across research fields that is increasingly coming to light poses a significant risk to scientific progress. Not only does research into the replicability of psychology and economics research reveal pronounced difficulty in reproducing results, but the findings also emphasize the need across the literature to develop experimental tasks and procedures that can be easily adopted by other researchers (Camerer et al., 2016). For this reason, the Savings Game is freely available for use at https://github.com/o-nate/savings-game and may be freely tested at https://savingsgame.org (Lawrence, 2024c, 2024b).

Further, as Camerer et al. (2016) postulate, economics experiments may demonstrate greater replicability than psychological ones through proper incentivization—offering appropriate financial remuneration to motivate subjects. We find that the Savings Game achieves this incentivization as well, in particular by tying remuneration to subjects' savings rather than consumption. Doing so both more closely simulates the decision-making process subjects face in real life—where saving money can itself produce utility—as well as consolidate the in-task inflation's insidious effect, facilitating subjects' inflation internalization.

Finally, given the replicability of the Savings Game, there are a number of directions that future research can take in applying and varying the experimental task. For one, testing new inflation sequences offers a straightforward path. New sequences can allow us to study the role that variance in inflation plays on behavior as well as how deflation may impact behavior. We can also add new levels of complexity to the Savings Game as a means of approaching decisions that subjects more commonly face in real life, such as including additional goods, offering credit, or simulating monetary policy by adjusting the interest rate. Informational—rather than educational—interventions approaches might also be tested, such as providing the inflation rate or even the real interest rate on the screen. The possibility of informational interventions also raises the question of what information subjects pay attention to or utilize most during the Savings Game. Eye-tracking technology offers one option for tracking attention. Another, simpler method is to implement the Mouselab programming language within the interface, hiding each piece of information on the screen behind individual boxes, requiring the subject to click on each to reveal the information while measuring the order and amount of time spent collecting each piece of information (Gabaix et al., 2003).

As such, the Savings Game, and experimental methods of inflation research generally, offer a number of future possibilities not just for understanding how rising prices affect household consumers' behavior, but for uncovering the underlying relationships contributing to consumption and savings decision-making as well as effective methods to help households develop more productive financial habits and attain greater financial security.

Chapter 3:
Inflation expectations in time and frequency, a wavelet analysis[19]

This chapter presents a novel perspective and analytical approach to a long-standing debate: the relationship between inflation expectations and household consumption and savings behavior. With the recent return of inflation instability among developed economies, understanding how households behave in the aggregate when faced with rising prices is key to monetary policy. A fundamental component of such behavior, households' inflation expectations remain a closely watched, yet little understood trend, one for which economic research continues producing inconsistent, at times conflicting, results. Despite some recognitions of the cyclicity in such trends, there has been little formal research into the cyclical nature of this expectations-behavior relationship. As such, to seek these possible cyclical natures, I explore an approach known as wavelet analysis. Wavelet analysis allows me to examine series in both the time and frequency (i.e. cyclical) domains. I apply this technique to US inflation expectations, nondurables and durables personal consumption, and personal savings data over a long period of time, from 1978 to 2024. Through the new perspective provided by the frequency domain, I show how the often-inconsistent aggregate relationships between expectations and consumption and savings behavior in macroeconomic data may in fact be consistent, the very result of the series' multi-scale cyclical natures.

[19] This chapter is based off Lawrence, N. (n.d.). *Inflation expectations in time and frequency: A wavelet analysis* (LEMMA Working Paper). Université Paris-Panthéon-Assas, LEMMA.

1. INTRODUCTION

Inflation can produce pronounced negative impacts on households' financial well-being. Understanding how households anticipate inflation and ultimately behave is paramount for monetary policy and consumer protection strategies and ultimately economic stability.

Since the 1990s and prior to the COVID-19 pandemic, households in developed economies faced nearly no inflation. During the last significant inflationary period in developed economies, most notably in the 1970s and 1980s, macroeconomic data revealed pronounced shifts in households' savings and consumption behaviors as a function not only of the inflation rate they faced, but of the rate they anticipated facing. Research at the time found that increases in the rates of households' expected inflation correlated with increases in their consumption of nondurable goods, or "stocking up." Decreases in anticipated inflation similarly correlated with increased savings rates (Juster & Wachtel, 1972; Katona, 1974). In other words, when households expected prices to rise in the future, they would naturally make more purchases in the present; when they did not anticipate price hikes, rather, they would maintain or grow their savings.

Since then, however, the literature has been anything but conclusive on the relationship between households' inflation expectations and behavior not only from an empirical perspective, but even a theoretical one as well. Theoretical research does consistently show, however, that households' ability to accurately anticipate inflation is critical for their productive economic decision-making (D'Acunto et al., 2022; Gautier & Montornès, 2022). Unfortunately, empirical research consistently shows that households typically demonstrate quite inaccurate expectations of inflation (Abildgren & Kuchler, 2021; Cornand & Hubert, 2022; Jungermann et al., 2007), which ultimately confound their decision making.

During the 1970s and 1980s in developed economies, households regularly under-anticipated inflation; they would then save during periods of rising prices, unknowingly doing so at negative real interest rates (Stephens & Tyran, 2017). As Katona (1974) postulates, when consumers underestimated future inflation during this time period, they failed to recognize the role inflation was playing on their subsequently worsening financial state. Consumers, instead, misinterpreted their increasing financial hardship as being simply the result of a "bad economy" or poor personal financial management and, thus, believed they needed to save more and/or act more financially responsibly—as opposed to limiting exposure to losses of wealth in real value.

As such, when facing inflation, households' ability to accurately anticipate inflation and then time their behavioral changes accordingly ultimately defines whether such actions produce economic benefit or harm. Improper behavioral changes can reduce one's purchasing power, in particular, by either underexposing wealth to increases or overexposing to decreases in real value, such reducing (increasing) money held in savings accounts with positive (negative) real interest rates.

That said, contemporary research has produced inconclusive, and at times conflicting, empirical results on the relationships between expected inflation and household behavior (Andrade et al., 2023; Binder, 2017; D'Acunto et al., 2022).[20] For instance, Burke and Ozdagli (2021) find little impact on consumption behavior in the United States, while Dräger and Nghiem (2021), Ichiue and Nishiguchi (2015), and Andrade et al. (2023) find positive relationships in Germany, Japan, and France respectively between the inflation rate households expect and their consumption. Moreover, Coibion et al. (2021) find a positive and negative relationship between expectations and nondurables and durables respectively in the US. Nevertheless, as Coibion et al. (2021) point out, inflation expectations and consumption decisions can be endogenous and, therefore, difficult to disentangle through macroeconomic data.

Ramsey (2002) proposes that part of the endogeneity problem may arise from the cyclical nature of consumers' behavior, which is often overlooked in economic modeling. Not only do consumers make decisions at competing time horizons, but in

[20] See D'Acunto et al. (2022) for a contemporary summary of research on inflation expectations.

the aggregate, these competing time horizons across heterogeneous agents can produce macroeconomic phenomena that are difficult to disentangle without analyzing the cyclical nature of the series themselves. In other words, we must analyze trends not just in the time domain, but the frequency[21] domain as well to understand the cyclical nature underlying this economic relationship.

In this chapter, I present an original approach based on *wavelet analysis* that allows me to identify the economic trends' cyclical periods. This wavelet analysis provides us with a new perspective and method to disentangle the relationship between inflation expectation and consumption.

This chapter proceeds as such. Section 2 first reviews the current literature on inflation expectations and consumer behavior then presents wavelet analysis, its theoretical foundation as well as application economics. Section 3 presents the wavelet analysis of inflation expectations, consumption, and savings data from the United States, while further explaining the wavelet techniques applied. Finally, Section 4 discusses the results.

2. LITERATURE REVIEW

2.1. Expected inflation

There exists a broad literature emphasizing inflation expectations as a key factor in inflationary and monetary-policy outcomes; however, the underlying mechanisms through which these variables interact at the macroeconomic level remain little understood (Abildgren & Kuchler, 2021; D'Acunto et al., 2022). Furthermore, the very relationship between inflation and economic stability and growth has, itself, proven difficult to disentangle (Bernanke, 2007).

[21] I.e. in terms of cyclical periods

Even at the theoretical microeconomic level, the relationship between expected inflation and consumption is unclear. For example, all else equal, an increase in expected inflation suggests a decrease in expected real interest rates and, thus, implies an increase in consumption and decrease in savings—exemplified by the Euler consumption equation (Dräger & Nghiem, 2021). But, a similarly feasible mechanism is that an increase in households' expected inflation can imply a reduction in the real value of their assets, leading them to reduce consumption to protect wealth—in other words a *precautionary behavior* (Gautier & Montornès, 2022). When examined at the aggregate empirical level, results can vary widely and at times conflict (D'Acunto et al., 2022; Gautier & Montornès, 2022). From a theoretical perspective, though, we may categorize the two possible relationships as relating to either the *Euler-consistent* behavior—increases in expected inflation lead to increases in consumption—or *precautionary* behavior—increases in expected inflation lead to increases in savings.

There has been a significant amount of empirical recent research at the macroeconomic level. According to the detailed review of contemporary literature on inflation expectations by D'Acunto et al. (2022), the results obtained on the whole are conflicting or inconsistent. In particular, while, there is clear evidence that households' inflation expectations and consumption decisions correlate, the underlying mechanism remains unclear.

That said, contemporary empirical research has revealed consistency in regards to some notable stylized facts. Of note, household consumers consistently:

1. overestimate inflation;
2. offer estimates that vary distinctly, based on socio-demographic factors, such as age, gender, income, and education-level; and
3. align expectations with overall economic sentiment (Abildgren & Kuchler, 2021; Reiche & Meyler, 2022).

How these stylized facts relate to household behavior at the macroeconomic level, though, remains unclear.

One challenge that contemporary empirical research confronts is that households' inflation expectations and consumption behavior are elicited through survey methods, such as the Michigan Survey of Consumers or Survey of Consumer Expectations in the United States (D'Acunto et al., 2022). Both surveys are rotating panels; this complicates the research by limiting the time horizon across which the relationship can be analyzed. Further, for consumption behavior, the surveys rely on respondents accurately remembering and predicting their behavior, rather than tracking their actions and purchases.

The controlled experiments presented in Chapter 1 and Chapter 2 demonstrate at the micro-level that subjects' inflation expectations relate positively to their resulting consumption behavior. The results validate the survey methods employed to elicit inflation expectations at the macroeconomic level. Further, the results provide evidence that a positive relationship between expectations and consumption can be identified using actual consumption behavior data, rather than the qualitative responses upon which current survey methods rely. Building upon this work, the aim of this chapter is now to compare these results to macroeconomic data.

Given the challenges of survey-elicited consumption behavior, I choose compare inflation expectations directly to personal expenditure on consumer goods and personal savings data. Using this macro-level "behavioral" data, though, risks introducing only greater inconsistency in the trends. As Ramsey (2002) underscores:

- the endogeneity between expectations and behavior may arise from underlying cyclical, wave-like, patterns in consumption, and
- consumption at competing time horizons across a multitude of heterogeneous agents can produce seemingly unintelligible macroeconomic phenomena.

The difficulty this cyclical nature poses to econometric analysis can be summarized using a simple "cartoon" example shown in Figure 19. Here, we see two basic sinusoidal functions. The top panel shows the functions "in-phase," moving in a completely synchronized manner; the middle panel shows an "anti-phase" relationship, where the functions move in a completely oppositional manner; and the bottom panel shows the function "out of phase" by a quarter cycle ($\frac{\pi}{2}$). As a result, there are periods in the latter's case where the two functions demonstrate a positive relationship and others, negative; however, this apparent inconsistency in the relationship is, in fact, the result of the cyclicity inherent to their behavior. Therefore, studying the cyclical nature of series can help uncover the underlying phenomena producing apparently inconsistently macroeconomic behavior.

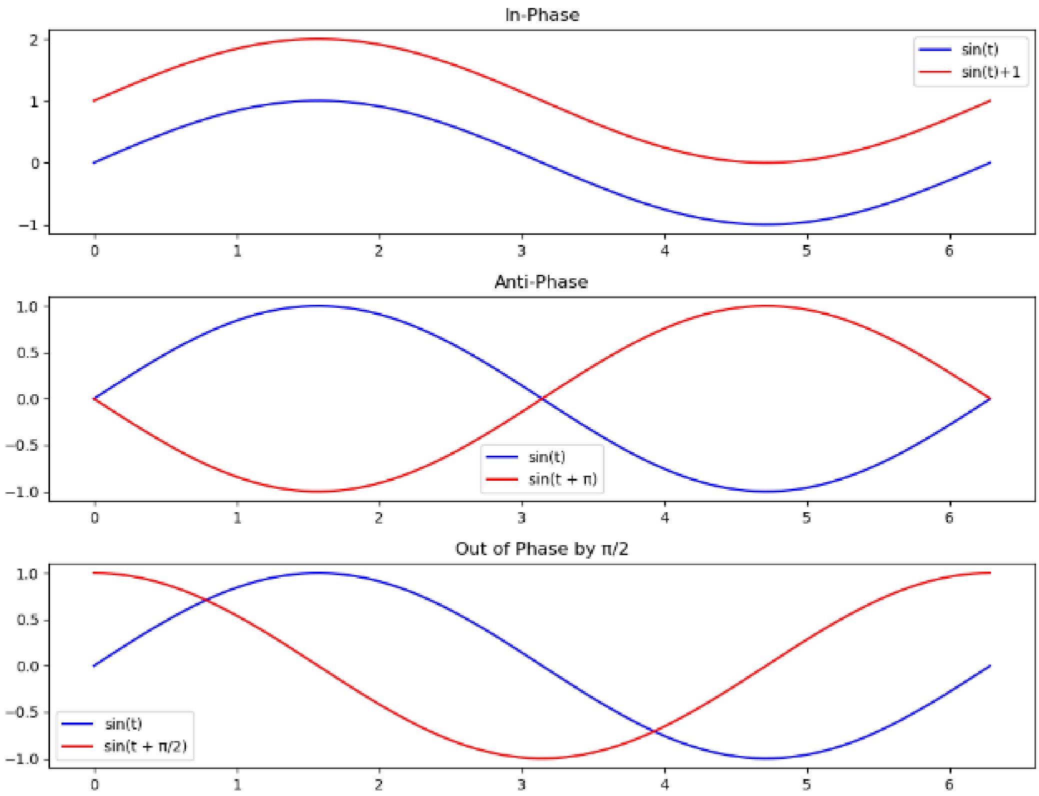

Figure 19 - Example: The impact of phase on the relationship between cyclical trends

To my knowledge, the relationship between inflation expectations and consumption has yet to be studied from the perspective of cyclicity, in terms of periodic variation. One method to gain such a perspective is through the use of wavelet analysis.

The next section presents this method and explains why it could be an efficient solution to address this gap. In Section 3. Analysis: Inflation expectations, consumption, and savings, we apply this analysis to examine the cyclical behavior of inflation expectations and consumption and savings and compare the relationship between them across different frequencies (i.e. cyclical periods or time-horizon windows).

2.2. Wavelet analysis

2.2.1. Theoretical framework

Normally, to analyze the cyclicity of a series, we would use the Fourier transform, which allows us to translate a series in the time domain to the frequency domain. From a theoretical perspective, essentially any periodic function can be decomposed into a series of sine and cosine waves. Joseph Fourier originally proved this in relation to thermodynamics, and over the ensuing two centuries, the applications of the Fourier transform have extended over many fields of study (Bracewell, 1989).

By transforming a series from the time to the frequency domain, the Fourier transform produces a frequency *spectrum* like in Figure 20 below. This spectrum acts like a fingerprint of the composite frequencies that make up a given series. Figure 20 shows two sets of time series in the left panels. The upper-left panel shows four sinusoidal functions with differing frequencies, or periodic oscillations in terms of time t. The Fourier transform calculates the frequency of each series in terms of $\frac{1}{t}$.[22], allowing us to plot the identified frequencies in the upper-right panel. Similarly, we can apply a Fourier transform to the series in the lower-left panel. In doing so, we produce a frequency spectrum identical to that of the upper-right. This result implies that the series in the lower-left panel is, in fact, resulting aggregation of the combined series in the upper-left panel.

[22] The example measures time t in terms of seconds (s). Hertz (Hz) is simply one cycle per second, $1/_s$. Therefore, as frequency increases, the number of cycles per unit time increase.

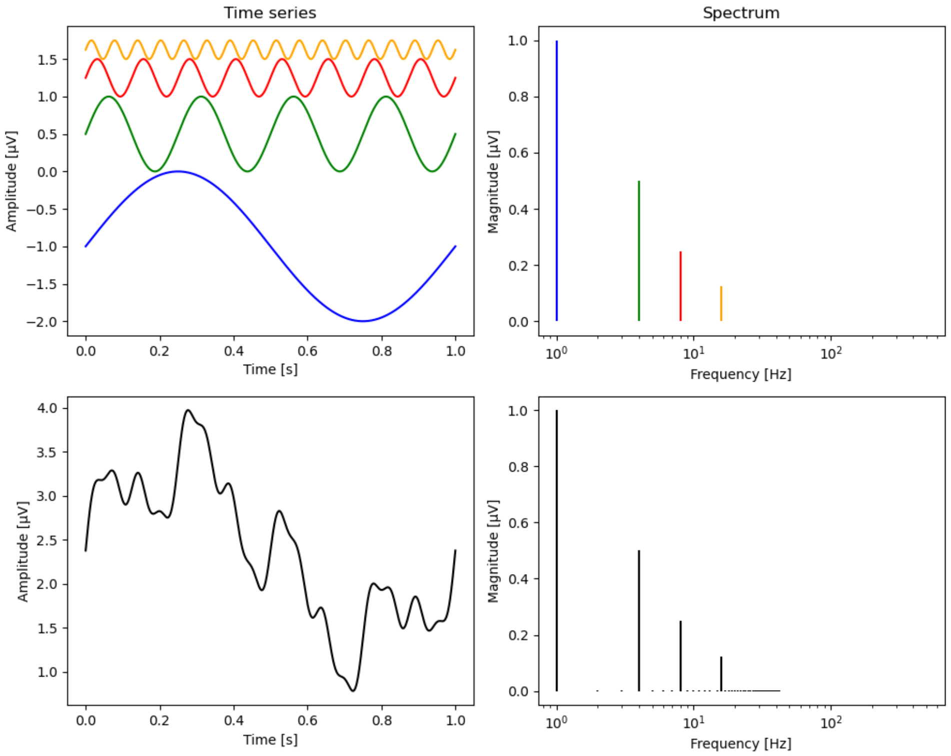

Figure 20 - Fourier transform[23]

This process of converting from time to frequency offers clear advantages. The frequency domain is a unique and important perspective without which it can be difficult to identify underlying trends. Even in the simple example in Figure 20, identifying the composite frequencies—of which there are merely four—is nearly impossible when viewed purely from the time-domain perspective on the left-hand side. In the frequency domain on the right-hand side, though, the relationship is immediately obvious.

That said, this fingerprint that the frequency spectrum generates also demonstrates a key drawback of the Fourier transform in that it requires series that are stationary, for which the same composite frequencies persist (theoretically, to infinity). This requirement makes economic time series especially difficult to analyze through Fourier transforms.

[23] This example is based on the explanation by Bach and Meigen (1999).

Wavelet analysis offers a conveniently flexible alternative. Based off the Fourier transform, the wavelet transform uses "wavelet" functions that are localized in both the time and frequency domain, rather than using sine and cosine functions that are infinite in time (Schleicher, 2002). Wavelets' coexistent time and frequency localization allows us to analyze nonstationary time series in the frequency domain through the wavelet transform, which is otherwise impossible with the Fourier transform. In other words, *with wavelets, we can measure how the frequency spectrum changes over time*.

While the bulk of the theory behind wavelets is beyond our present scope, to understand the fundamental concept underpinning our analysis, the following key concepts of wavelets are presented below.[24]

First, as mentioned above, wavelets are localized in both time and frequency. A wavelet may be essentially any function ψ that behaves like a wave (i.e. goes up and down as a function of time t), such that $\int_{-\infty}^{\infty} \psi(t)dt = 0$; in other words, the area under the curve at $y > 0$ is equal to the area at $y < 0$. Different than the Fourier transforms' infinite sines and cosines, though, $\psi(t)$ must also satisfy $\int_{-\infty}^{\infty} \psi(t)^2 dt = 1$ and $\int_{-T}^{T} \psi(t)^2 dt = 1 - \epsilon$, where $\epsilon > 0$—the latter implying that the wavelet peters out beyond $-T \leq t \leq T$ (Aguiar-Conraria & Soares, 2010; Ramsey et al., 2010). Figure 21 provides examples of wavelet functions and their respective frequency spectra via the Fourier transform.[25]

[24] For further information, one should consult Percival and Walden (2000) and Daubechies (1992) for detailed mathematical guides and Aguiar-Conraria and Soares (2010), Gallegati and Semmler (2014), Rua (2010), and Schleicher (2002) for guides on applications in economics.
[25] See Torrence and Compo (1998) for additional examples.

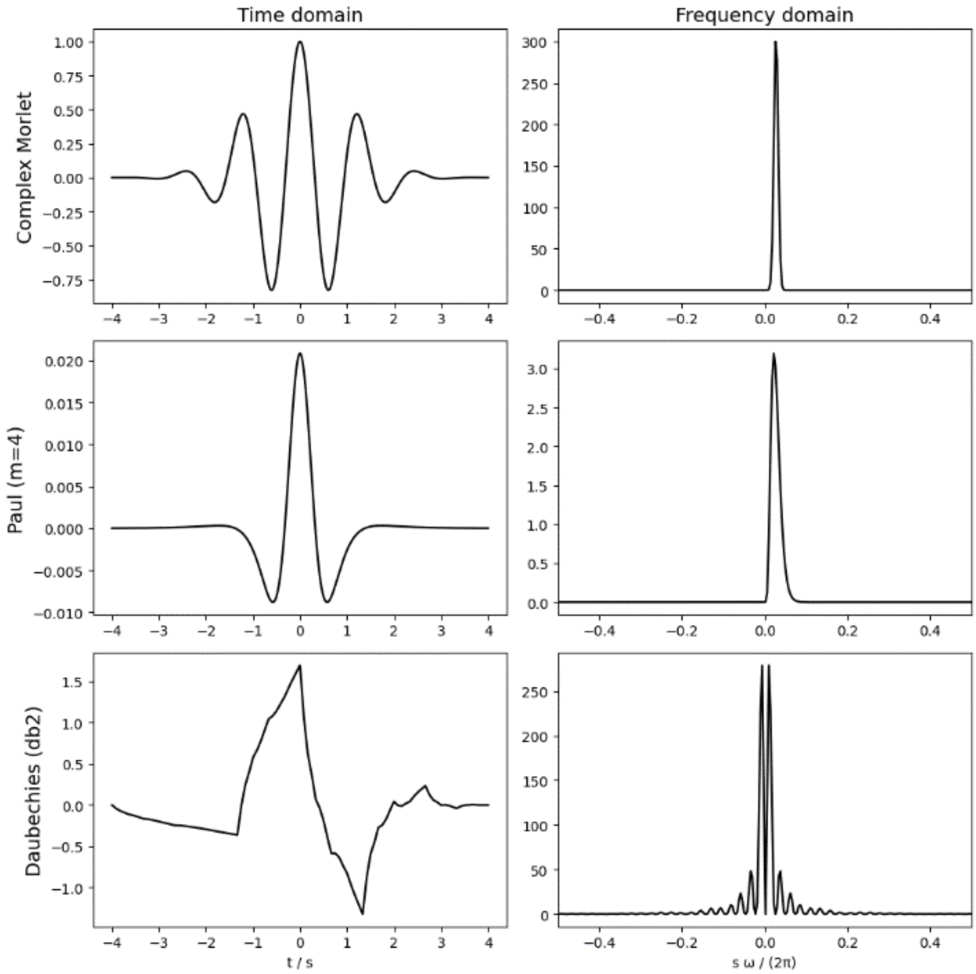

Figure 21 - Example Wavelet Functions

Second, the wavelet can be scaled and translated to produce "daughter" wavelets $\psi_{\tau,s}$ from the original "mother" function ψ:

$$\psi_{\tau,s}(t) \coloneqq \frac{1}{\sqrt{|s|}}\psi\left(\frac{t-\tau}{s}\right), \qquad s,\tau \in \mathbb{R}, s \neq 0 \tag{1}$$

where s is a scaling factor that stretches or compresses ψ along the time axis and τ is a translation factor that shifts ψ along the time axis. Each daughter wavelet $\psi_{\tau,s}$ corresponds to a particular frequency and is projected onto the original series $x(t)$ to identify the frequency components. Generally speaking, the wavelet transform is:

$$W(s,\tau) = \int_{-\infty}^{\infty} \psi_{s,\tau}(t)x(t)dt \tag{2}$$

Practically speaking, this function represents the process of iteratively stretching (or shrinking) the mother wavelet and projecting each iteration onto the series being analyzed along the time axis to measure how the frequency spectrum changes over time.

Third, the wavelet transform of $x(t)$ in equation 2 represents a "continuous wavelet transform" (CWT). There exists a computationally more efficient "discrete wavelet transform" (DWT) with daughter wavelets:

$$\psi_{jk}(t) = 2^{-\frac{j}{2}}\psi\left(\frac{t-2^{j}k}{2^{j}}\right) \tag{3}$$

at scales $s = 2^{j}$, $j = 1,2, \dots J$ and time index $k = 1,2, \dots N/2^{j}$, where N is the number of observations in series $x(t)$ (Ramsey et al., 2010). By projecting $\psi_{j,k}(t)$ on $x(t)$, we obtain a coefficient for the $d_{j,k} \approx \int \psi_{j,k}(t)x(t)dt$ for each scale and time index (j,k). This discretization leaves us with the ability to reconstruct $x(t)$:

$$x(t) \approx S + \sum_{k} d_{J,k}\psi_{J,k}(t) + \sum_{k} d_{J-1,k}\psi_{J-1,k}(t) + \cdots + \sum_{k} d_{1,k}\psi_{1,k}(t) \tag{4}$$

where S represents the averaged series at each scale, calculated with the scaling function "father wavelet" ϕ by:

$$\phi_{J,K}(t) = 2^{-\frac{J}{2}}\phi\left(\frac{t-2^{J}k}{2^{J}}\right) \tag{5}$$

With the scaling coefficients $s_{J,k} \approx \int \phi_{J,k}(t)x(t)dt$, we can reconstruct the signal:

$$x(t) \approx \sum_{k} s_{J,k}\psi_{J,k}(t) + \sum_{k} d_{J,k}\psi_{J,k}(t) + \sum_{k} d_{J-1,k}\psi_{J-1,k}(t) + \cdots + \sum_{k} d_{1,k}\psi_{1,k}(t) \tag{6}$$

Rewriting the summations of coefficients in equation 6, we state $x(t)$ in terms of a smooth component and series of detail component vectors, where the frequency scale increases as $J \to 1$:

$$x(t) \approx S_J + D_J + D_{J-1} + \cdots + D_1 \tag{7}$$

where S_J shows the zoomed-out road map and D_1 shows the potholes (Ramsey et al., 2010).

With this set of smooth and component vectors, we can deconstruct and reconstruct the original $x(t)$ series and analyze it across and at different, specific frequencies.

2.2.2. Wavelets in economics

Within economics, the CWT is especially useful for exploratory analysis. In particular, we can compare the CWTs of two distinct economic time series to identify the time and frequency intervals where they interact. The ability to decompose series into component frequencies makes the DWT useful within existing econometric applications, such as denoising and regression (Gallegati et al., 2014, 2019).

As described by Ramsey and Lampart (1998), the DWT allows us to conduct *time scale regression*, where we regress output variables on input variables at each j frequency level individually within a set of models:

$$y[S_J]_t = \alpha_J + \beta_J x[S_J]_t + \epsilon_t \tag{8}$$

and

$$y[D_j]_t = \alpha_j + \beta_j x[D_j]_t + \epsilon_t \tag{9}$$

for the smooth component's independent and dependent variables, $y[S_J]_t$ and $x[S_J]_t$, respectively and for the j-level detail scale's independent and depend variables, $y[D_j]_t$ and $x[D_j]_t$, respectively for $j = 1, 2, \dots, J$.

The literature on wavelets in economics is still relatively small, but there have been noteworthy findings regarding other areas of economic study with similarly conflicting results in the literature. For example, Ramsey and Lampart (1998) use time scale regression to find variation in the relationship between income and consumption as a function of frequency scale. Gallegati et al. (2014) and Aguiar-Conraria et al. (2020) both find similar variations in the relationship between productivity and unemployment at different frequency scales. More relevant to our present analysis of inflation, Gallegati et al. (2011) find evidence supporting the Phillips Curve across frequency scales. Rua (2012) finds evidence that the relationship between the money supply and inflation exists primarily at lower frequencies (i.e. longer time-cycle horizons), while Gallegati et al. (2019) similarly find supporting evidence for the Quantity Theory of Money at longer time-cycle horizons of 16 to 24 years. Further, Martins and Verona (2023) find evidence that inflation expectations exhibit strong influence on headline inflation dynamics at lower frequencies, whereas energy price inflation is a more prominent determinants at higher frequencies.

Considering the challenges in identifying a relationship between inflation expectations and consumption, applying a wavelet analysis seems worthwhile to disentangle their dynamics as well.

3. ANALYSIS: INFLATION EXPECTATIONS, CONSUMPTION, AND SAVINGS

My objective is to analyze the relationships between expected inflation and consumption using wavelet techniques, assessing the approach's effectiveness. To maintain a reference point within the literature, I compare the trends observed in the analysis to a benchmark model. Coibion et al. (2021) provide a particularly recent model with US data, breaking the relationship down between both nondurables and durables. Further, their survey includes actual purchase data via the Kilts-Nielsen Consumer Panel.[26]

[26] The Kilts-Nielsen Consumer Panel tracks roughly 80,000 households' consumption data, registered through the use of in-home barcode scanners that panelists use to register the products they purchase (Coibion, Gorodnichenko, et al., 2021; *NielsenIQ: Consumer Panel and Retail Scanner Data*, 2024).

Through their survey, Coibion et al. (2021) find that inflation expectations have a positive relationship with nondurables (and services) consumption and a negative relationship with durables consumption. A 1% increase in inflation expectations correlates with a 1.8% increase in nondurables consumption and 1.5% decrease in durables consumption.

My objective is not to replicate their exact model and results but rather compare the aggregate behavioral trends that they observe through recent survey data in our aggregate data. Whereas their model directly uses individuals' survey responses, mine uses time series of the corresponding aggregated indicators. I use the discrete wavelet, continuous wavelet, and cross-wavelet transforms as well as time scale regression.

The analysis consists of three parts. First, I present descriptive statistics of the series in the time domain. Then, I apply wavelet transforms to gain new perspectives on the data. These transforms include the discrete wavelet transform (DWT) to observe each frequency component separately; the continuous wavelet transform (CWT) to track the evolution of the frequency components' explanatory power over time; and the cross-wavelet transform, described below, to analyze the evolution over time of the relationships between inflation expectations and nondurable, durables, and savings at each frequency. Finally, I conduct a time scale regression to quantify the relationships between inflation expectations and nondurable, durables, and savings at each frequency.

All analysis is conducted in Python, using the statsmodels, PyWavelets, and PyCWT libraries (Krieger & Freij, 2023; Lee et al., 2019; Perktold et al., 2024). The code is freely available for use at https://github.com/o-nate/inflation-wavelets (Lawrence, 2024a).[27]

[27] At the current time of writing, the code is not "production" ready, meaning it has not been fully tested on other computers. My intention is to make this a standalone program, freely available online, where people can generate wavelet transforms of their own time series data.

3.1. Descriptive statistics

For my analysis, I use the one-year inflation expectations indicator generated by the University of Michigan's Surveys of Consumers, and the personal consumption expenditures for nondurable and durable goods, and personal savings between January 1, 1978 and July 1, 2024.[28] All time series provide observations on a monthly basis. I retrieve all data through the FRED API from the Federal Bank of St. Louis (*St. Louis Fed Web Services: FRED® API Overview*, n.d.).

Figure 22 graphs the four series over time. The bottom three panels compare inflation expectations to the percent change in personal nondurables and durables consumption as well as the personal savings rate;[29] the top panel compares inflation expectations to CPI inflation (University of Michigan, 2024; U.S. Bureau of Economic Analysis, 2024b, 2024a, 2024d; U.S. Bureau of Labor Statistics, 2024). Visually inspecting the series, it proves very difficult to identify any sort of relationship between expectations and consumption and savings.

[28] Personal consumption expenditures: Nondurable goods (PCEND), Personal consumption expenditures: Durable goods (PCEDG), and Personal saving (PMSAVE)

[29] Here, I graph the Personal Saving Rate (PSAVERT) to simplify the visualization, but in my analysis, I use the gross Personal Saving (PMSAVE).

Figure 22 - Time series: Inflation, Inflation Expectations, Nondurables Consumption, Durables Consumption (US)

Table 32 shows descriptive statistics for the CPI inflation; inflation expectations; and the percent change in nondurables consumption, durables consumption, and savings (University of Michigan, 2024; U.S. Bureau of Economic Analysis, 2024a, 2024b, 2024c; U.S. Bureau of Labor Statistics, 2024), similar to those used by Kim and In (2005). CPI inflation and inflation expectations share nearly identical means, but CPI inflation has varied more over the same time period. Nondurables and durables consumption also share similar mean percent changes; however, durables consumption has also varied much more over time. The percent change in savings is significantly higher on average and varies much more than the other variables. All variables are fairly skewed to the right, except for nondurables. Although the percent change in nondurables has close to normal skewness and kurtosis, Jarque-Bera and Shapiro-Wilk tests confirm that none of the variables are normally distributed. The Ljung-Box tests further show that the data are autocorrelated as well.

Table 32 - Descriptive statistics (1978-2024)

	CPI inflation	**Expectations**	**Nondurables (% change)**	**Durables (% change)**	**Savings (% change)**
Observations	559	559	559	559	559
Mean	3.60	3.59	5.11	5.55	10.94
Standard deviation	2.78	1.62	3.83	7.25	42.54
Skewness	1.80	2.51	0.39	2.33	2.89
Kurtosis	3.65	6.27	3.43	23.37	16.80
Jarque-Bera	601.64***	1480.98***	280.92***	12987.82***	7224.63***
Shapiro-Wilk	0.83***	0.67***	0.95***	0.84***	0.76***
Ljung-Box	7891.17***	8192.97***	2628.26***	1462.64***	1156.48***

For the wavelet analysis, rather than the percent change in the series, I use the logarithmic difference. The reasoning for this is partly that logarithmic differences are additive, where a decrease of 0.01 represents an equal change in magnitude to that of an increase of 0.01, whereas a 10% increase or decrease are not equal in absolute magnitude. Additionally, households are indeed notoriously imprecise with their point estimates (Abildgren & Kuchler, 2021; Cornand & Hubert, 2022; Jungermann et al., 2007). Their qualitative expectations (i.e. stating whether they expected prices to increase, decrease, or stay the same), however, can prove more accurate and a better predictor of subsequent behavior (Andrade et al., 2023). In fact, we validate this greater predictive power of qualitative expectations experimentally in Chapter 2. Therefore, I choose to use the logarithmic difference—rather than the direct inflation rate expected in percentage terms—to compare how changes in households' expectations relate to their consumption and savings behavior. That is to say that a positive (negative) logarithmic difference implies an increase (a decrease) in expectations, so I compare that change in outlook to the corresponding change in behavior.

Being the case, though, the interpretation of logarithmic difference can be less intuitive, so I spare us the descriptive statistics here. They are essentially the same, though, aside from the distribution of nondurables appearing much less normal. See Appendix C

Table 1 in Appendix C.1. Additional descriptive statistics for the logarithmic difference results.

Subsequently, Table 33 presents a correlation matrix of the series' logarithmic differences. There are clear positive correlations between CPI inflation and both inflation expectations ($p \leq 0.01$) and nondurables ($p \leq 0.01$) as well as a negative correlation with savings ($p \leq 0.05$). Inflation expectations, however, only demonstrate a statistically significant correlation with nondurables ($p \leq 0.01$); with durables and savings, the correlation is essentially zero. Further, nondurables and durables are positively correlated ($p \leq 0.01$), and we also confirm that savings do indeed correlate negatively with both consumption series ($p \leq 0.01$).

Table 33 - Correlation matrix: Logarithmic differences of series (1978-2024)

	CPI inflation	**Expectations**	**Nondurables**	**Durables**	**Savings**
CPI inflation	—				
Expectations	0.24***	—			
Nondurables	0.42***	0.16***	—		
Durables	0.03	-0.03	0.39***	—	
Savings	-0.12**	0.04	-0.27***	-0.31***	—

3.2. Exploratory wavelet analysis: New perspectives

3.2.1. Frequency decomposition

As originally suggested by Ramsey (2002), decomposing two series into their corresponding detail and smooth components individually and comparing them visually provides a helpful initial exploratory step, allowing us to identify variations in synchronicity and changes in lead-lag relationships (i.e. which series appears to lead or follow the other). This decomposition requires the discrete wavelet transform (DWT).

I apply the DWT to the inflation expectations and nondurables, durables, and savings at each frequency series. Similar to Kim and In (2005), I use the Daubechies 4 asymmetric wavelet since it is effective at localizing features within a series (Bruzda, 2011; Daubechies, 1992). Figure 23 shows the decomposition of inflation expectations, with the lowest frequency (i.e. largest cycle) S_6 smooth component in the top panel and the highest frequency D_1 detail component in the bottom panel. This figure is the wavelet-transform equivalent of the upper-left panel in Figure 20 above.

Each level j represents a time scale interval 2^j, such that the detail components D_1, D_2, D_3, D_4, D_5, D_6 contain cycles of 2-4, 4-8, 8-16, 16-32, 32-64, and 64-128 months respectively. S_6 represents the long-term trend, while each component D_j represents the deviations from this trend in the cyclical interval (Gallegati et al., 2014).

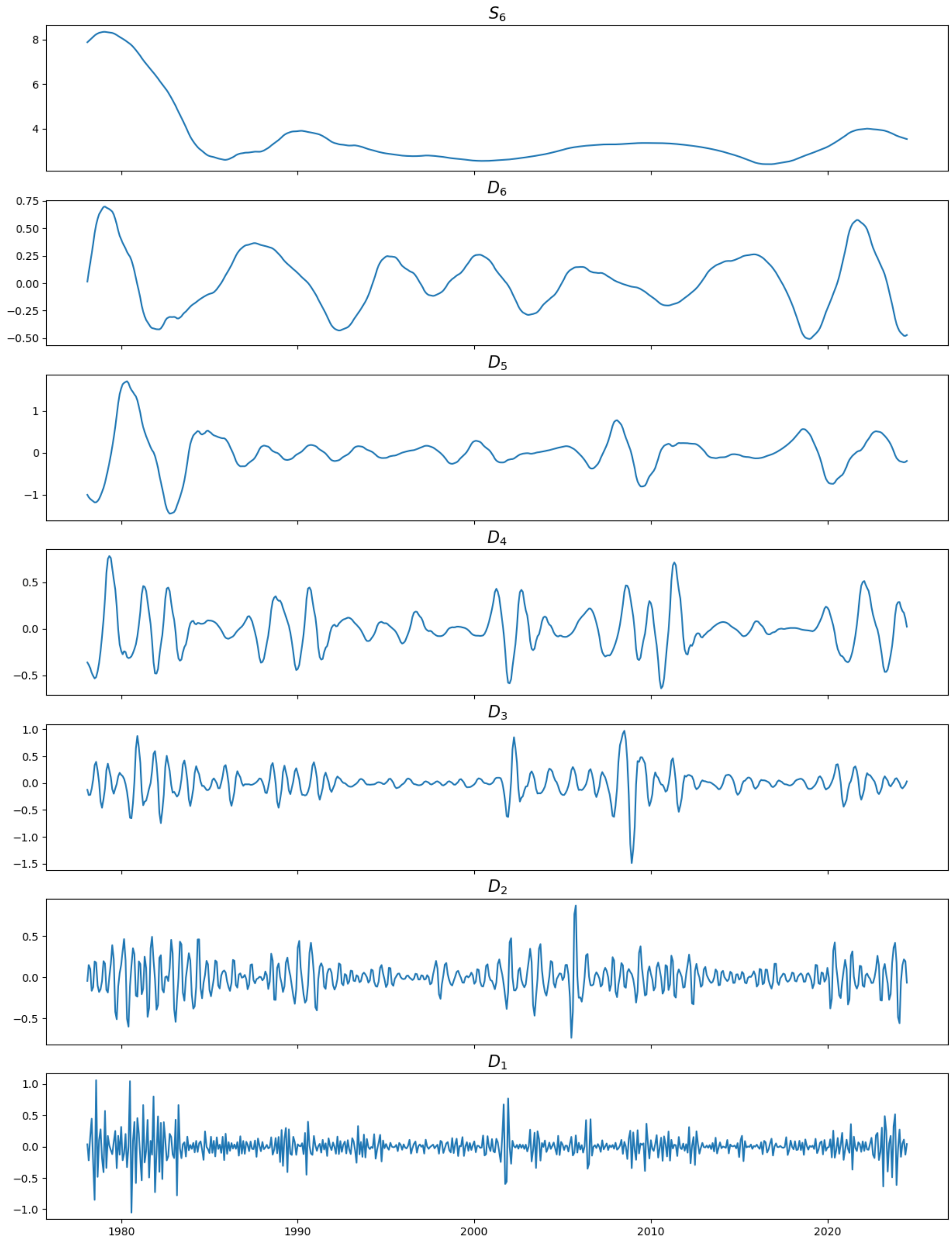

Figure 23 - Frequency decomposition of inflation expectations

Of immediate note, the highest frequency components, D_1 and D_2, contain the most noise. In fact, by decomposing the series into discrete frequencies, we can denoise the series by reconstructing it with an inverse DWT and simply removing the noisiest detail components, D_1 and D_2 for instance. Given equation 7, where the DWT of a series $x(t)$ of scale J produces components such that

$$x(t) \approx S_J + D_J + D_{J-1} + \cdots + D_1$$

we can remove (add) detail components to the smooth component S_J to produce increasingly smooth (detailed) approximations S_{J-k} of $x(t)$ (Gallegati et al., 2014; Ramsey et al., 2010), where k is the number of detail components included. Figure 24 visualizes this possibility of approximating additional smooth components,

$$x_{exp}(t) \approx S_6 + D_6 + \cdots + D_1$$

$$S_1 = S_6 + D_6 + D_5 + D_4 + D_3 + D_2$$

$$S_2 = S_6 + D_6 + D_5 + D_4 + D_3$$

$$\cdots$$

$$S_5 = S_6 + D_6$$

$$S_6 = S_6,$$

where the S_1 smooth component approximates the inflation expectations series without the D_1 detail component. The top panel shows the approximation of the S_1 smooth component. Moving from the top to bottom panel, we iteratively remove the next level detail component.

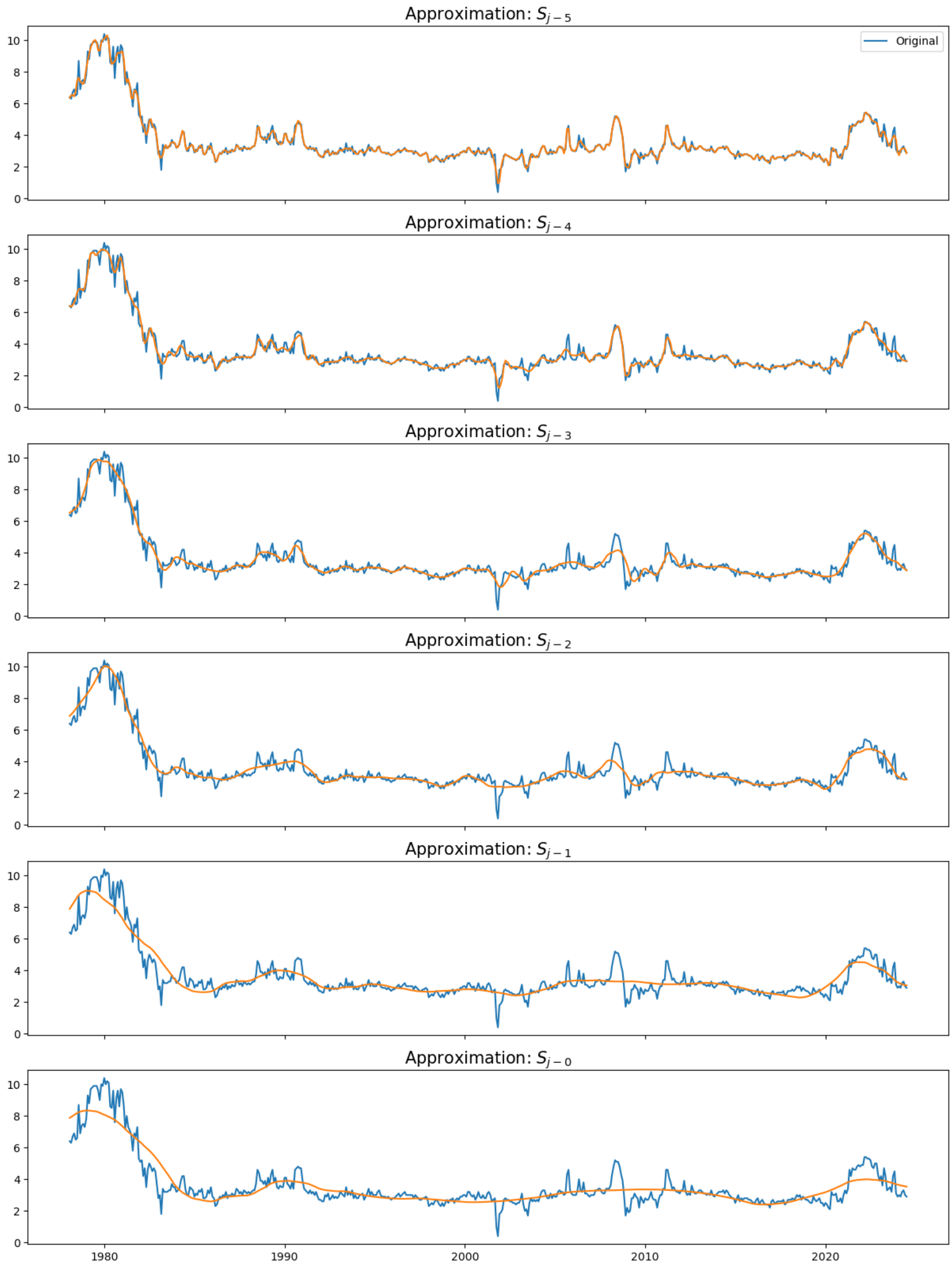

Figure 24 - Smoothing of inflation expectations through inverse DWT and detail-component removal

Moreover, this decomposition via the DWT allows us to compare series at each frequency too. Figure 25 presents the comparative frequency decompositions of inflation expectations and nondurables consumption, juxtaposing in terms of percent expected and percent change as originally presented against the logarithmic differences of the two. First, comparing percent and logarithmic differences, we remark a distinct spike in inflation expectations in terms of logarithmic difference in the D_1 and D_2 detail components around 2001. The D_5 and D_6 detail components reveal distinct cyclical behavior in the series as well as synchronization between them. But their amplitudes differ greatly and, in fact, such that the amplitude of nondurables percentage change is much larger than that of inflation expectations, while the opposite is true for logarithmic difference. We should note that there is a difference in interpretation between the left-hand and right-hand panels; whereas the left-hand depicts how nondurables consumption is changing at a given moment in time with the corresponding inflation expectation level, the right-hand shows how nondurables consumption is changing (in terms of logarithmic difference) at a given moment with the corresponding *change* in inflation expectations in terms of logarithmic difference.

Also, of note, the two series do appear primarily in-phase. But, this co-movement disperses in terms of percentage, given relatively stable inflation expectations between 1990 and the early 2000s, at which point the series' amplitudes become more pronounced from 2008 through 2013. The relationship again disperses, given the flattening of inflation expectations, until right before 2020, when their amplitudes again increase. In terms of logarithmic difference, though, we observe in the D_5 and D_6 components that the sensitivity of households' inflation expectations may have been greater than is immediately apparent from the raw estimations. Generally speaking, the series exhibit in-phase behavior, rising and falling together, in both D_5 and D_6. Such cyclical behavior should, indeed produce a positive, *Euler-consistent* relationship, like we see both in the correlations in Table 33 and Appendix C Table 2 (in Appendix C.1. Additional descriptive statistics) as well as in Coibion et al. (2021).

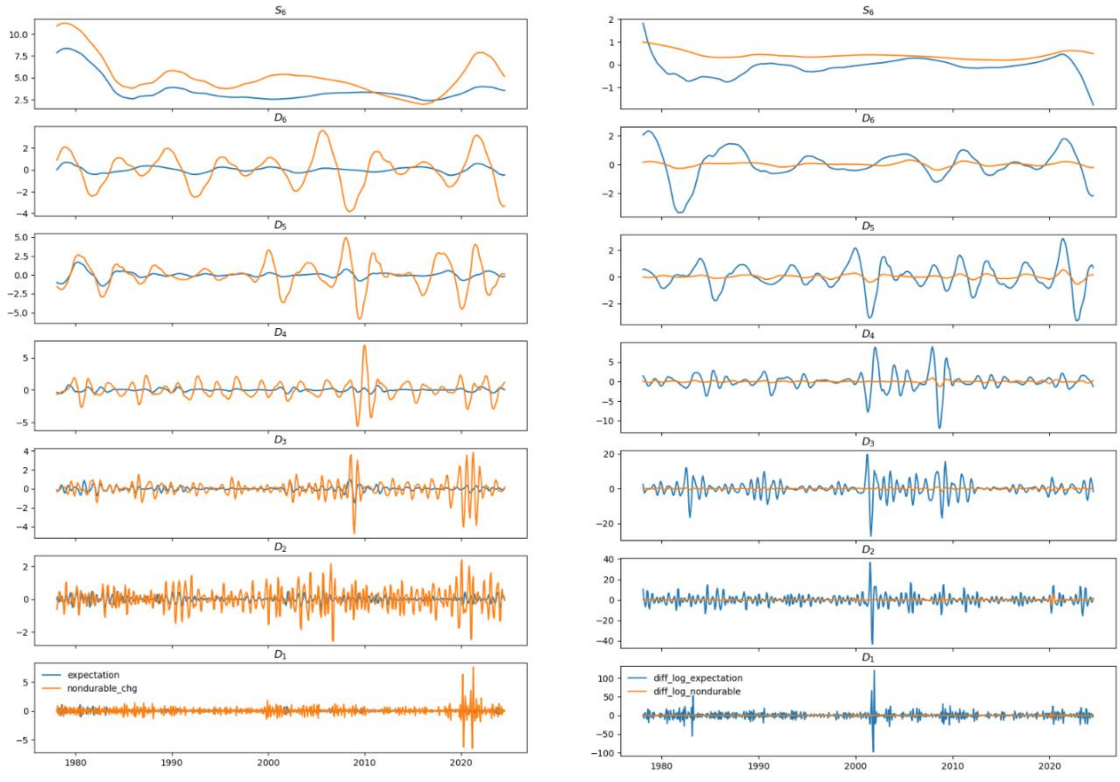

Figure 25 - Frequency decompositions: Inflation expectations and nondurables consumption

Next, we examine the smooth S_6 and detail components $D_j, j = 1 \dots 6$ of inflation expectations and durables consumption in Figure 26 in terms of percent expected and percent change on the left and logarithmic differences on the right.

Interestingly, there are clear time intervals of an anti-phase relationship (i.e. one rises while the other falls), especially in the S_6 component. This is consistent with the findings of Coibion et al. (2021), whereby individuals demonstrate a negative relationships between expectations and durables consumption—*precautionary* behavior. Nevertheless, the high degree of shifting between in- and anti-phase in the detail components suggests that Euler-consistent aggregate behavior may also arise—particularly in periods of instability, such as the 2008 financial crisis and start of the COVID-19 pandemic in 2020. These intervals of in-phase relationship are particularly apparent in the D_5 and D_6 components.

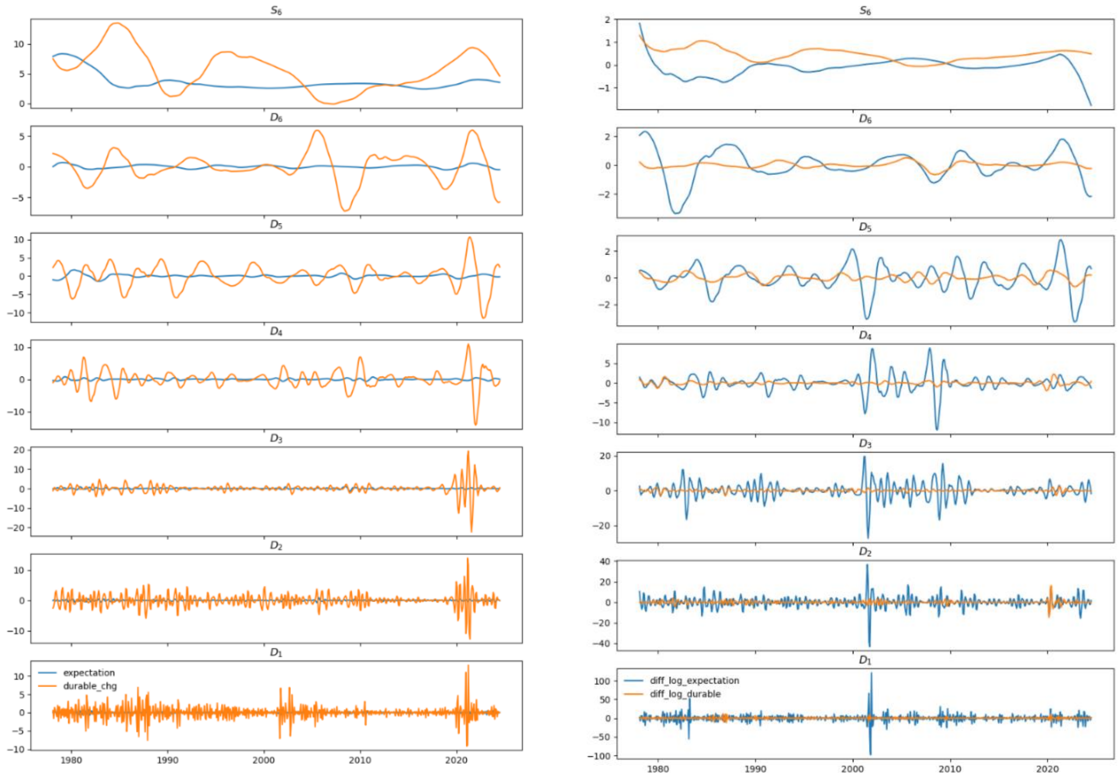

Figure 26 - Frequency decompositions: Inflation expectations and durables consumption

Finally, Figure 27 compares inflation expectations and savings, with the left-hand decomposition showing the percent expected and the savings rate and the right-hand, the logarithmic differences of expectations and savings.

Perhaps the most striking feature at first glance is the utterly linear decrease in savings rate in the S_6 component from the end of the 1970s to right before the 2008 financial crisis. In addition, inflation expectations and savings—both in rate and logarithmic difference—appear quite in-phase in S_6. Detail components D_6 and D_5, however, present mainly anti-phase behavior, while D_4 and D_3 seem to contain intervals of in-phase and intervals of anti-phase. Taken together, we might suspect a pattern of precautionary behavior at least over the longest time horizon (i.e. lowest frequency, S_6 component) and one of Euler-consistent behavior of the medium-term, as per D_6 and D_5.

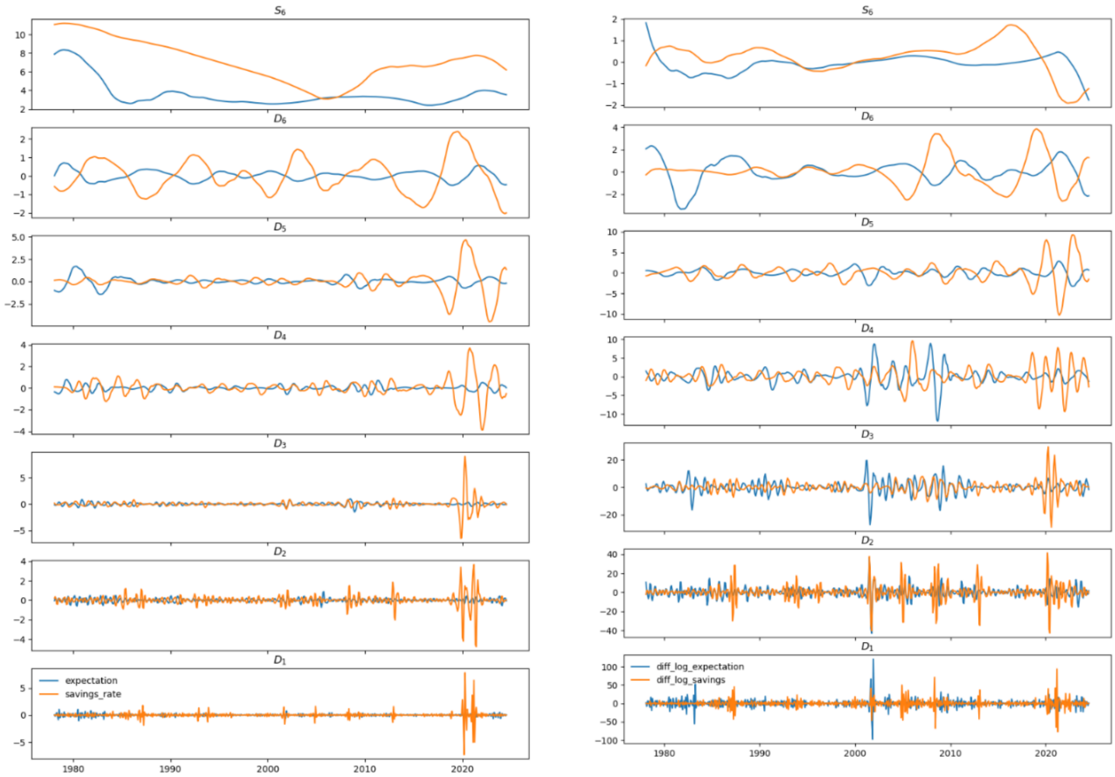

Figure 27 - Frequency decompositions: Inflation expectations and savings

This preliminary analysis, based purely on visual inspection of the components, though, does not allow us to determine the phase and lead-lag between the variables in a consistent manner. A consistent manner requires the continuous wavelet transform (CWT), cross-wavelet transform (XWT), and wavelet phase-difference, which will allow us to extract additional information from each series that is otherwise undetectable in the time domain.

3.2.2. Individual time series: Continuous wavelet transforms

Summarizing the detailed explanation by Aguiar-Conraria and Soares (2010), the continuous wavelet transform (CWT) allows us to plot how our variables' spectral characteristics evolve over time through a wavelet power spectrum.[30,31] The CWT and

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[30] The wavelet power spectrum is sometimes referred to as a scaleogram or wavelet periodogram.
[31] In essence, this is like mapping how the frequency spectrum generated by the Fourier transform evolves over time.

wavelet power spectrum, therefore, offer a more detailed method for us to analyze the component changes in a series over time.

The CWT of a series $x(t)$ is defined as:

$$W_{x;\psi}(\tau, s) = \langle x, \psi_{\tau,s} \rangle = \int_{-\infty}^{\infty} x(t) \frac{1}{\sqrt{|s|}} \psi^* \left(\frac{t - \tau}{s} \right) dt \tag{10}$$

Subsequently, the Fourier transform allows us to represent W_x in terms of frequency ω as well:[32]

$$W_x(\tau, s) = \frac{\sqrt{|s|}}{2\pi} \int_{-\infty}^{\infty} \Psi^*(s\omega) X(\omega) e^{i\omega t} d\omega \tag{11}$$

This duality allows us to map shifts in frequencies' amplitude, or "power", within our series over time through the wavelet power spectrum:

$$(WPS)_x(\tau, s) = |W_x(\tau, s)|^2 \tag{12}$$

Applying the CWT to our target series produces the four wavelet power spectra below.

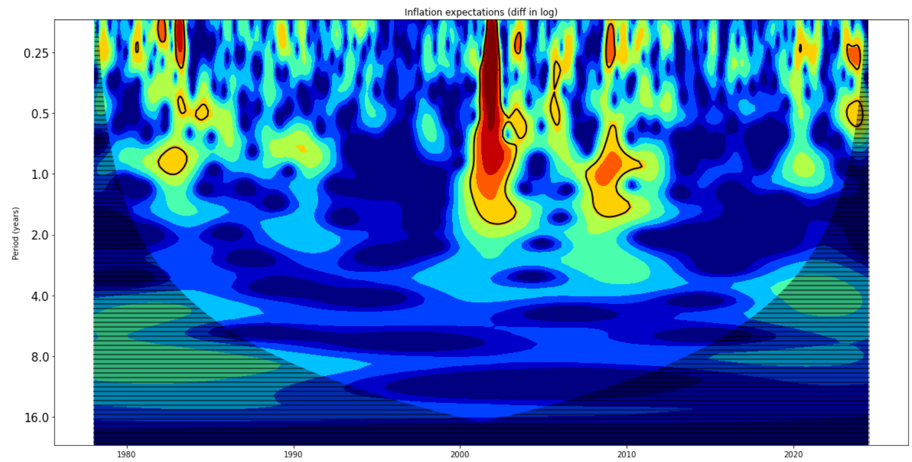

Figure 28 - Power spectrum: Inflation expectations

[32] Note that common notation for $W_{x;\psi}$ is simply W_x.

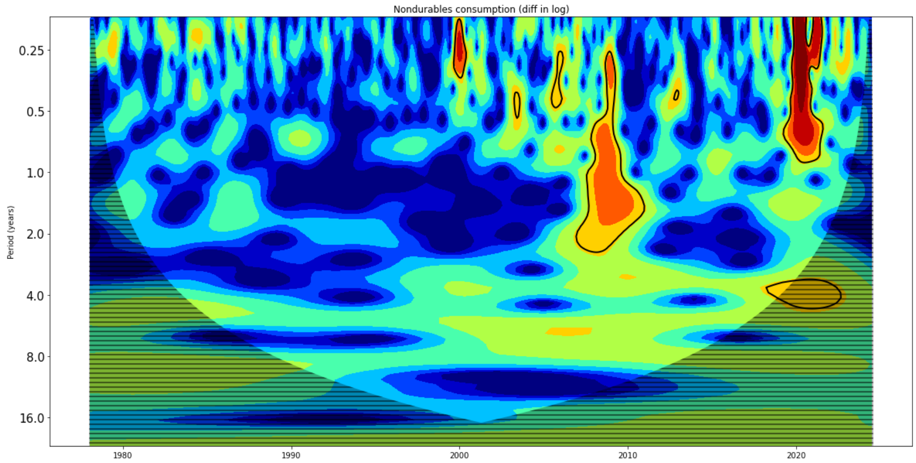

Figure 29 - Power spectrum: Nondurables consumption

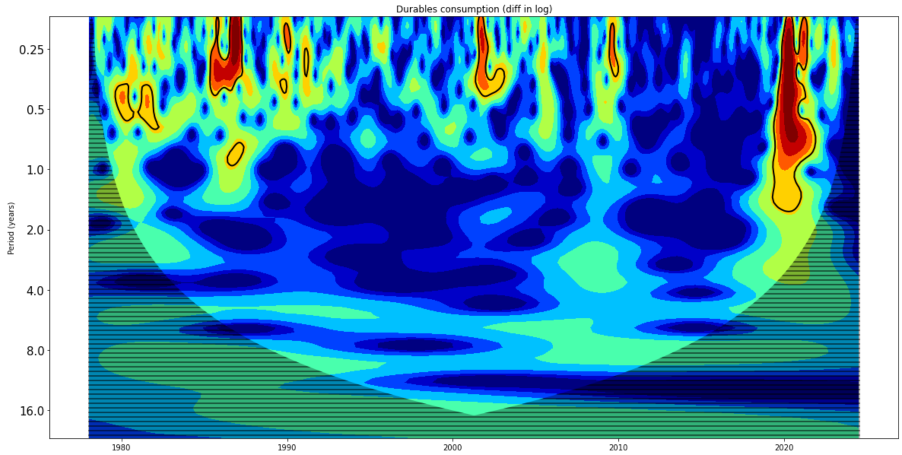

Figure 30 - Power spectrum: Durables consumption

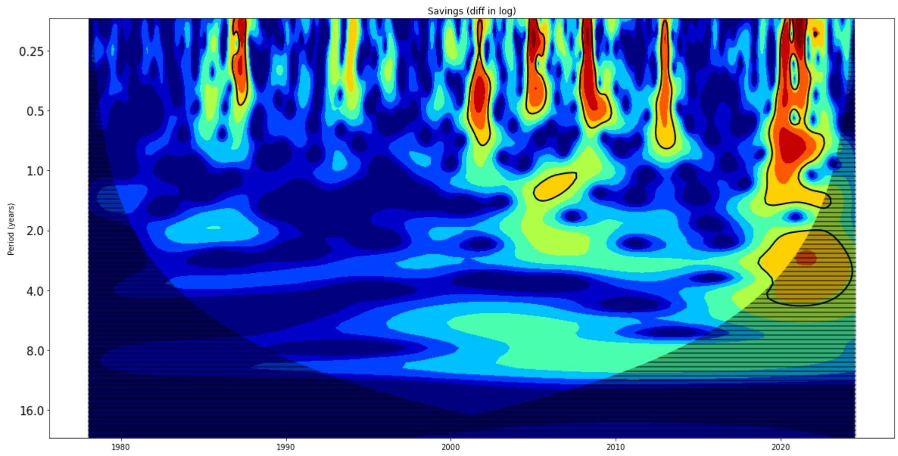

Figure 31 - Power spectrum: Savings

The power spectra in Figure 28, Figure 29, Figure 30, and Figure 31 show the changes in explanatory power of frequencies within each series over time, in terms of logarithmic difference.[33] The y axis displays the frequencies in terms of periods (where frequency and period are inverses) so as to frame the units in years; a frequency of $\frac{1}{2}$ has a period of 2 years. Areas in blue are low-power and red high-power. Black contours encircle areas of statistical significant ($p < 0.05$) using Monte Carlo simulation and chi-square distributions (Torrence & Compo, 1998). Finally, the shaded region along the edges and bottom represent areas where edge affects arise from the CWT, known as the "cone of influence" (COI). The cone of influence occurs because the series must be padded with zeros at the beginning and end to fit the complete cycle of each daughter wavelet ψ_s.[34] Results within the COI should be interpreted with caution since they include artificially padded zeros.

In Figure 28, we see that the logarithmic differences in inflation expectations primarily demonstrate more power over shorter periods (higher frequencies) between three months an and one year. There are, however, notable and statistically significant jumps in power at higher frequencies in the early 1980s and around more recent periods of crisis: the 2001 burst of the tech bubble, the 2008 financial crisis, and the 2020 start of the COVID-19 pandemic.

In Figure 29 and Figure 30, nondurables and durables consumption logarithmic differences also demonstrate consistently higher power spectra at higher frequencies of up to one year in period with jumps in power around the 2001 tech bubble, 2008 financial crisis, and COVID-19 pandemic. Both series also seem to contain an underlying, lower-power frequency at a four- to eight-year cycle, roughly in-line with the business cycle (Addo et al., 2014; Aguiar-Conraria et al., 2011).

Interestingly, in Figure 31, we see no underlying power at the business-cycle level until around 2000. Rather, the logarithmic difference of savings shows bursts of high-power

[33] See Appendix C.2. Continuous wavelet transforms of series in percentage terms for the CWT power spectra of the series in percentage terms, similar to the time series and frequency decompositions in percentage terms.
[34] Note that this implies that the cone of influence is a function of the wavelet function chosen (Torrence & Compo, 1998).

at high frequencies during periods of economic turmoil but otherwise appears inconsistent—possibly a reflection of the steady trend down in savings in the United States since the 1980s.

Taken together, we observe that most power within the four series exists at higher frequencies, with jumps in power around crises. Next, I compare these observed trends between each CWT $W_x(\tau, s)$ using the cross-wavelet transform.

3.2.3. Time series co-movements: Cross wavelet transforms and phase difference

While the CWT of each series $W_x(\tau, s)$ provides a detailed view through the power spectrum, we cannot directly compare them. Direct comparison requires the cross-wavelet transform (XWT) and resulting cross-wavelet power spectrum.

Given two time series $x(t)$ and $y(t)$, the cross-wavelet transform $\left|W_{xy}\right| = |W_x W_y|$ represents the covariance between x and y at each scale and frequency (Gallegati et al., 2014). We can produce a cross-wavelet power spectrum to identify the time-frequency regions where x and y show commonly high power.

Further, wavelet functions ψ and their corresponding CWTs $W_x(\tau, s)$ can be real or complex. In the latter case, the real $\Re\{W_x(\tau, s)\}$ and imaginary components $\Im\{W_x(\tau, s)\}$ capture the amplitude $|W_x(\tau, s)|$ and phase $\phi_x(\tau, s)\colon W_x(\tau, s) = |W_x(\tau, s)|e^{i\phi_x(\tau,s)}$ respectively.[35] By extracting these two sets of information in the real and imaginary components, we can determine the phase as (Aguiar-Conraria & Soares, 2010):

$$\phi_x(\tau, s) = \text{Arctan}\left(\frac{\Im\{W_x(\tau, s)\}}{\Re\{W_x(\tau, s)\}}\right) \tag{13}$$

[35] Note that the use of ϕ is not related to the father wavelet function, as mentioned in 2.2.1. Theoretical framework.

Given XWT W_{xy}, we can similarly calculate the difference between two series' phases ϕ_x and ϕ_y, known as the "phase difference" ϕ_{xy} through:

$$\phi_{xy} = \text{Arctan}\left(\frac{\Im(W_{xy})}{\Re(W_{xy})}\right) \tag{14}$$

which is simply $\phi_{xy} = \phi_x - \phi_y$ (Aguiar-Conraria & Soares, 2010). We then map this phase difference onto the cross-wavelet power spectrum over time and frequency in the form of vector arrows.

Figure 32 provides a key for interpreting the arrows. An arrow pointing in the right or left direction, with an angle of either $\theta \approx 0°$ or $\theta \approx 180°$, implies in- or anti-phase relationship respectively. Right and up $(0° < \theta < 90°)$ represents x leading y in-phase, left and down $(90° < \theta < 180°)$ x leading y anti-phase, right and down $(180° < \theta < 270°)$ y leading x in-phase, and left and up $(270° < \theta < 360°)$ y leading x anti-phase.[36]

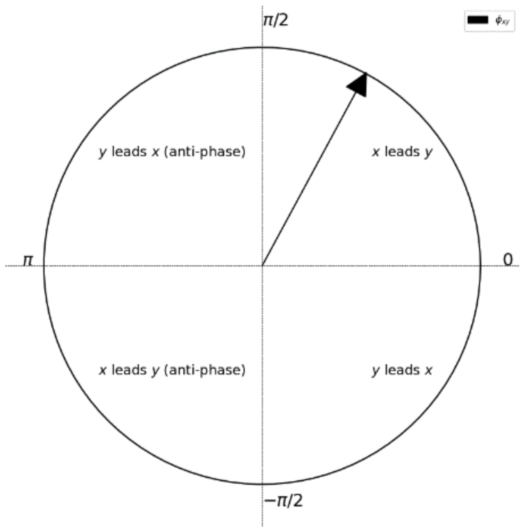

Figure 32 - Key, Phase Difference

[36] As can be seen in Figure 32, the angle θ can equally be represented in terms of radians, where $90° = \frac{\pi}{2}$.

For example, within the context of inflation expectations and nondurables consumption, an in-phase relationship (i.e. an arrow pointing to the right as represented in Figure 32) would reflect a positive relationship with expectations and consumption moving in the same direction, and thus suggesting Euler-consistent behavior. Conversely, an anti-phase relationship (i.e. pointing leftward) would represent precautionary behavior.

The XWTs of logarithmic difference in inflation expectations with nondurables consumption, durables consumption, and savings produce the three cross-wavelet power spectra shown below. For the spectra in percentage terms, see Appendix C.3. Cross-wavelet transforms of series in percentage terms.

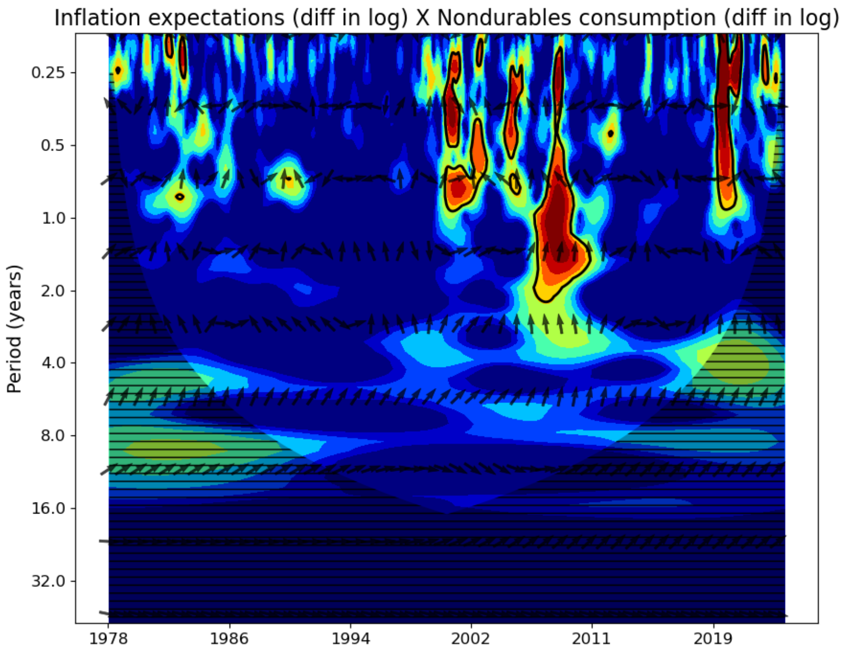

Figure 33 - Cross-wavelet power spectrum: Logarithmic differences of inflation expectations and nondurables consumption

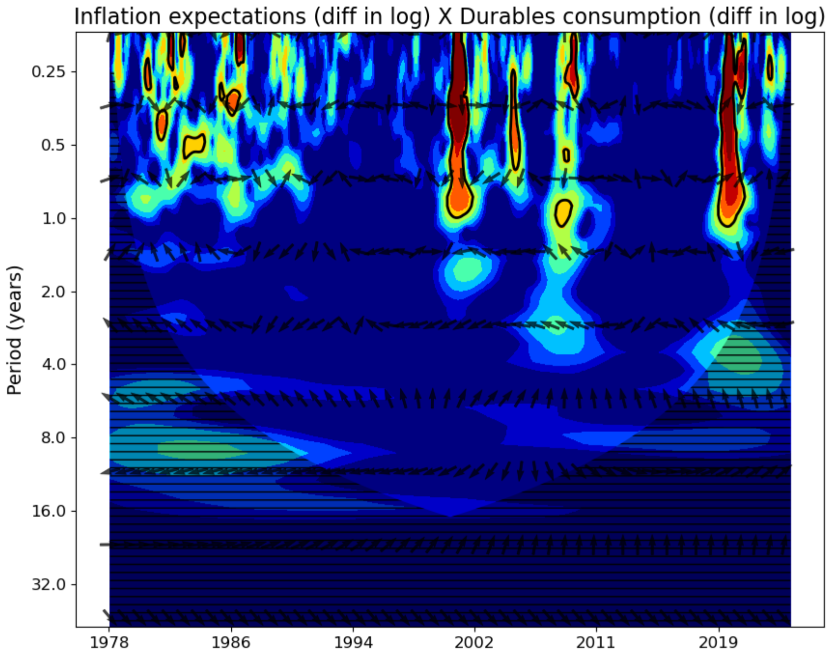

Figure 34 - Cross-wavelet power spectrum: Logarithmic differences of inflation expectations and durables consumption

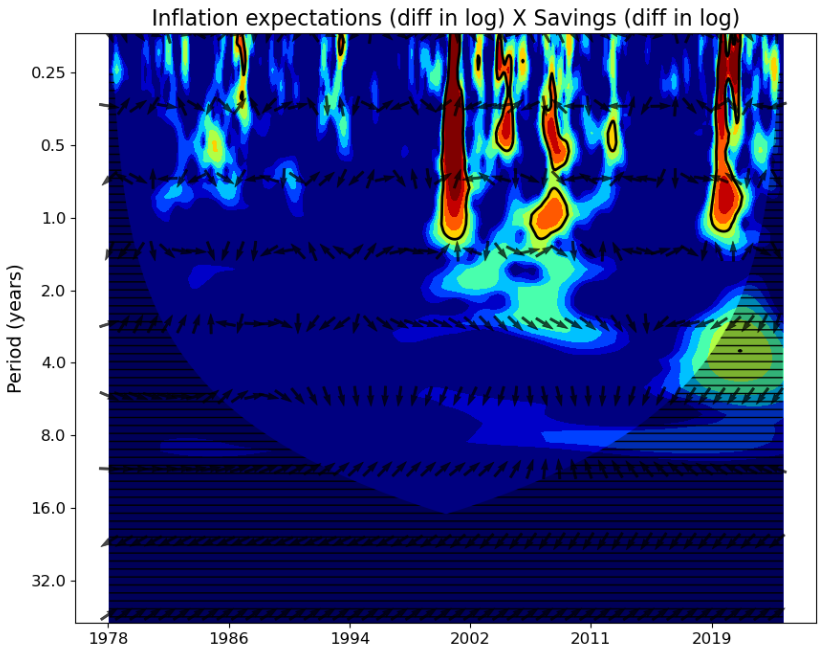

Figure 35 - Cross-wavelet power spectrum: Logarithmic differences of inflation expectations and savings

First, in Figure 33, we observe that co-movement between inflation expectations and nondurables spikes in higher frequencies at times of economic turmoil, the late 1970s, the 2001 tech bubble-burst, the 2008 financial crisis, and the beginning of the COVID-19 pandemic. For the most part, at periods of high power, either inflation expectations lead nondurables in an in-phase pattern (i.e. an arrow point at angle $0° < \theta < 90°$) or nondurables lead expectations in an anti-phase ($90° < \theta < 180°$). In the case of the former, this translates as a positive relationship, in line with an Euler-consistent behavior of US households, in which an increase (decrease) in the logarithmic difference of inflation expectations precedes a similar increase (decrease) in the logarithmic difference of nondurables consumption. For the latter, this signifies that an increase (a decrease) in the logarithmic difference of nondurables consumption precedes an opposite decrease (increase) in the logarithmic difference of inflation expectations, suggesting on the contrary a precautionary behavior of US households.

Figure 34 presents the cross-wavelet power spectrum between the logarithmic differences in inflation expectations and durables consumption. Here, we observe a similar pattern to that displayed in the power spectrum with nondurables, particularly with high power around the 2001 tech bubble across periods from three months to one year; however, there is much less power around the 2008 financial crisis. In fact, the phase difference during this period reveals anti-phase relationships (precautionary behavior) at periods of two years or shorter. Conversely, around the start of the COVID-19 pandemic, there is a clear shift to in-phase (Euler-consistent behavior), with expectations leading durables consumption. During the inflationary interval in the 1970s and 1980s, we see quite erratic shifts between in- and anti-phase, lead and lag behavior. This appears consistent with CPI inflation's significantly higher variance during this time interval, compared to the 2000s and 2010s,[37] complicating households' ability to not only anticipate inflation, but settle on a consumption behavior—be it Euler-consistent or precautionary. Nevertheless, as with nondurables, most of the

[37] See Appendix C Table 3 in Appendix C.1. Additional descriptive statistics for CPI inflation trends in each decade.

cross-wavelet power seems to exist between logarithmic differences in expectations and durables consumptions at periods of less than two years.

Lastly, Figure 35 displays the cross-wavelet power spectrum between the logarithmic differences in inflation expectations and savings. Compared to the previous spectra, we again see a similar pattern with high power in times of economic turmoil, particularly the 2001 tech bubble, 2008 financial crisis, and COVID-19 pandemic at periods from three months to one year. In contrast, there is little explanatory power during the interval from the 1970s to 1990s. The phase differences are also erratic, like for durables consumption, exhibiting periods of both in-phase (precautionary behavior) and anti-phase (Euler-consistent behavior).

Holistically, our primary take-away may be that the logarithmic differences in the series demonstrate greatest co-movement during times of economic turmoil: the 1970s and 1980s inflationary interval, the 2001 tech bubble-burst, the 2008 financial crisis, and the 2020 start of the COVID-19 pandemic. Moreover, this co-movement between the logarithmic differences is at high frequencies (i.e. shorter cyclical periods), suggesting that the mechanism—through which changes in inflation expectations relate to changes in behavior—operates at higher frequency as well (i.e. within shorter time horizon). This pattern appears consistent as well with the literature on inflation expectations and attention, whereby consumers pay greater attention to information on inflation during a phase change, when in a high-inflation environment (Cavallo et al., 2017; Weber, Candia, et al., 2023).

Interestingly, the cross-wavelet power spectra in percentage terms (expected inflation rate and percentage change in behavior) shows high power of co-movement at lower frequencies; see Appendix C.3. Cross-wavelet transforms of series in percentage terms.

One interpretation of this difference is that while the mechanism of changes in inflation expectations relating to changes in behavior may operate over a short time horizon, the mechanism through which the indicator data relate (i.e. the expected inflation rate and percentage changes in consumption and savings) may operate over a longer time horizon. Indeed, this difference between mechanisms and time horizons may be further reflected in the fact that in percentage terms, the phase relationships and low frequencies appear much more consistent and stable. For percentage change in nondurables, the relationship appears mainly anti-phase (precautionary) at low frequencies with periods greater than two years, where consumption leads expectations, but in-phase (Euler-consistent) at higher frequencies, during which expectations lead. The relationship with percentage change in durables seems mainly anti-phase (precautionary) but with shifts to in-phase (Euler-consistent) starting in the early 2000s in the range of four- to eight-year cycles. This also seems noteworthy considering a significant portion of durables may be purchased on a four- to eight-year basis. Expectations and the percentage change in savings demonstrate pronounced in-phase (precautionary) relationships in the range of one- to four-year cycles but anti-phase (Euler-consistent) and the eight-year.

Although observation of the cross-wavelet power-spectra do not provide conclusive results, they allow us to observe the changes in the relationships through additional dimensions beyond the one dimension provided in the original time series or even the two dimensions provided by the frequency decomposition. Through the cross-wavelet power spectra, we can in fact perceive the shifts in the relationships across both time and cyclical period.

Returning to the relationships observed by Coibion et al. (2021), whereby inflation expectations and nondurables are Euler-consistent while expectations and durables are precautionary, the power spectra may shed some light. In particular, the researchers conduct their survey between June and December 2018. The power spectra in percentage terms (see Appendix C Figure 5 and Appendix C Figure 6 in Appendix C.3. Cross-wavelet transforms of series in percentage terms) reveal in-phase arrow indicators for nondurables in the range of three- to six-month cycles between 2018 and 2019—Euler-consistent behavior. For durables, though, there are both in- and anti-phase indicators across these same frequency and time intervals, which may produce either Euler-consistent or precautionary behavior in the aggregate. Coupled with the much clearer anti-phase relationship in the same time interval across the range of lower frequencies, of one year or more, an aggregate precautionary behavior of US households seems then quite plausible.

3.3. Regression analysis

The exploratory analysis in the previous section provides us with new perspectives on the series and their relationships, particularly through the CWT and XWT. Frequency decomposition via the DWT, however, also offers a means to regress the series across the cyclical components, known as time scale regression (Gallegati et al., 2014; Kim & In, 2005; Ramsey & Lampart, 1998). This section aims to time-scale regress the behavioral series on inflation expectations.

3.3.1. Baseline model

First, to establish a baseline, we conduct “aggregate” ordinary least square (OLS) regressions of the logarithmic differences in nondurables and durables consumption and savings on the logarithmic difference in inflation expectations respectively.

The aggregate OLS regressions follow:

$$y_{non,t} = \alpha + \beta x_{exp,t} + \epsilon_t \tag{15}$$

$$y_{dur,t} = \alpha + \beta x_{exp,t} + \epsilon_t \tag{16}$$

$$y_{sav,t} = \alpha + \beta x_{exp,t} + \epsilon_t \tag{17}$$

As shown in Table 34, only $y_{non,t}$ demonstrates a statistically significant relationship with inflation expectations, and in fact, all three aggregate models provide very little explanatory power. That said, in the aggregate, we do observe positive relationships between the logarithmic differences in expectations and both nondurables (Euler-consistent) and savings (precautionary) as well as a negative relationship with durables (precautionary).

Additionally, we conduct the aggregate OLS regressions in percentage terms (see Appendix C Table 4 in Appendix C.4. Regressions in percentage terms) to compare to Coibion et al. (2021), who finds nondurables increases 1.8% with a 1% increase in expectations while durables consumption decreases by 1.5%. Our aggregate regressions show that nondurables similarly increase 1.5% but reveals no relationship involving durables.

Table 34 - OLS regressions: Behavioral series on inflation expectations, logarithmic differences

	$y_{non,t}$	$y_{dur,t}$	$y_{sav,t}$
α	0.4077***	0.4346***	0.3196
	(0.0475)	(0.1221)	(0.6718)
β	0.0134***	-0.0060	0.0437
	(0.0034)	(0.0088)	(0.0487)
r^2	0.0267	0.0008	0.0015
r^2 Adj.	0.0249	-0.0010	-0.0003

Standard errors in parentheses.

* p<.1, ** p<.05, *** p<.01

3.3.2. Time scale regression

As mentioned above, time scale regression involves regressing the component vector of our output variable at a given scale on the corresponding component vector of our input variable (Ramsey & Lampart, 1998). Following the approach first laid out by Ramsey and Lampart (1998), we conduct six regressions for:

$$y_{non}[S_J]_t = \alpha_J + \beta_J x_{exp}[S_J]_t + \epsilon_t \quad (18)$$

$$y_{non}[D_j]_t = \alpha_j + \beta_j x_{exp}[D_j]_t + \epsilon_t \quad (19)$$

$$y_{dur}[S_J]_t = \alpha_J + \beta_J x_{exp}[S_J]_t + \epsilon_t \quad (20)$$

$$y_{dur}[D_j]_t = \alpha_j + \beta_j x_{exp}[D_j]_t + \epsilon_t \quad (21)$$

$$y_{sav}[S_J]_t = \alpha_J + \beta_J x_{exp}[S_J]_t + \epsilon_t \quad (22)$$

$$y_{sav}[D_j]_t = \alpha_j + \beta_j x_{exp}[D_j]_t + \epsilon_t \quad (23)$$

where $y_{non}[S_J]_t$, $y_{dur}[S_J]_t$, $y_{sav}[S_J]_t$, and $x_{exp}[S_J]_t$ are the smooth components of the logarithmic difference of nondurables, durables, savings, and expectations respectively and $y_{non}[D_j]_t$, $y_{dur}[D_j]_t$, $y_{sav}[D_j]_t$, and $x_{exp}[D_j]_t$ are the corresponding detail components at scale j of each series.

The time scale regression of logarithmic differences in nondurables consumption on inflation expectations is shown in Table 35. Here, we see positive relationships across all components, suggestive of Euler-consistent behavior among US households at all frequencies.

Table 35 - Time scale regression: Nondurables consumption on inflation expectations, logarithmic differences

	S_6	D_6	D_5	D_4	D_3	D_2	D_1
α_j	0.4205***	0.0013	-0.0007	-0.0034	-0.0000	-0.0005	0.0001
	(0.0073)	(0.0035)	(0.0025)	(0.0068)	(0.0123)	(0.0235)	(0.0360)
β_j	0.0817***	0.1020***	0.1407***	0.0606***	0.0352***	0.0343***	0.0018
	(0.0183)	(0.0034)	(0.0026)	(0.0031)	(0.0028)	(0.0042)	(0.0031)
r^2	0.0346	0.6230	0.8448	0.4070	0.2170	0.1051	0.0006
r^2 Adj.	0.0328	0.6224	0.8446	0.4059	0.2156	0.1035	-0.0012

Standard errors in parentheses.

* p<.1, ** p<.05, *** p<.01

Table 36 provides the results of the time scale regression of logarithmic differences in durables consumption on inflation expectations. At the lowest frequency S_6 component as well as higher frequency D_3 component, we see a negative relationship, whereas at the D_6, D_5, and D_4 component frequencies, there is a positive relationship. This translates to Euler-consistent behavior within the range of periodic cycles between 16 and 128 months and precautionary behavior at the long-term cycle of over ten years and short-term of eight to 16 months. Further, although not statistically significant, the precautionary behavior appears plausible in the D_1 and D_2 components. In other words, within the business-cycle range, there is Euler-consistent behavior, but at higher and lower frequencies, the behavior could rather be precautionary.

Table 36 - Time scale regression: Durables consumption on inflation expectations, logarithmic differences

	S_6	D_6	D_5	D_4	D_3	D_2	D_1
α_j	0.4319***	-0.0086	-0.0059	-0.0047	0.0018	0.0006	-0.0000
	(0.0116)	(0.0079)	(0.0100)	(0.0172)	(0.0260)	(0.0718)	(0.0916)
β_j	-0.2131***	0.0555***	0.0837***	0.0400***	-0.0157***	-0.0105	-0.0072
	(0.0293)	(0.0077)	(0.0102)	(0.0079)	(0.0060)	(0.0129)	(0.0079)
r^2	0.0871	0.0861	0.1078	0.0444	0.0123	0.0012	0.0015
r^2 Adj.	0.0855	0.0845	0.1062	0.0427	0.0105	-0.0006	-0.0003

Standard errors in parentheses.

* p<.1, ** p<.05, *** p<.01

Subsequently, Table 37 shows the results of the time scale regression of logarithmic differences in savings on inflation expectations. The S_6 component and D_2 and D_3 components demonstrate a positive relationship (precautionary behavior), whereas at the D_6 and D_5 show a negative relationship (Euler-consistent behavior). Of note, the shift in behavior between precautionary at high frequencies to Euler-consistent at business-cycle frequencies back to precautionary at the lowest frequency is the same pattern we observe in the time scale regression of durables.

Table 37 - Time scale regression: Savings on inflation expectations, logarithmic differences

	S_6	D_6	D_5	D_4	D_3	D_2	D_1
α_j	0.2392***	0.0049	0.0389	0.0299	-0.0027	-0.0012	-0.0006
	(0.0318)	(0.0532)	(0.0869)	(0.1040)	(0.1803)	(0.3528)	(0.5179)
β_j	0.2258***	-0.3421***	-1.1523***	0.0650	0.1067**	0.1783***	0.0190
	(0.0799)	(0.0516)	(0.0884)	(0.0476)	(0.0415)	(0.0636)	(0.0449)
r^2	0.0142	0.0734	0.2341	0.0034	0.0118	0.0139	0.0003
r^2 Adj.	0.0124	0.0717	0.2328	0.0016	0.0100	0.0122	-0.0015

Standard errors in parentheses.

* p<.1, ** p<.05, *** p<.01

Finally, to again compare to the results of Coibion et al. (2021), we repeat the time scale regressions in terms of percentage in Appendix C Table 5, Appendix C Table 6, and Appendix C Table 7 in Appendix C.4. Regressions in percentage terms. Coibion et al. (2021) find that the 1.8% increase in nondurables and 1.5% decreases in durables consumption occurs within a six-month window following the inflation-expectation elicitation. As such, we can compare their results to those of the D_2 detail component in our time scale regression, which corresponds to a four- to eight-month cyclical period. Indeed, we find that nondurables consumption demonstrates a positive relationship ($p \leq 0.01$) in D_2 and durables a negative relationship ($p \leq 0.05$). Broadening to the D_1 and D_3 components, these relationships hold, although, only to a statistically significant degree for the D_3 detail component of nondurables ($p \leq 0.01$).

4. DISCUSSION

Defining a clear empirical relationship between inflation expectations and consumption has remained elusive for economists. As our present findings suggest, the ambiguity in the literature may very well be the result of more complex underlying relationships.

Through wavelet analysis, we project otherwise one-dimensional time series data onto two- and then three-dimensional space and study their cyclical natures over time and in relation to each other. Further, we decompose and then regress the time series by frequency scale to better understand how their aggregate observable behavior arises from their different—and often competing—cyclical components. Indeed, this method does reveal underlying complexity that can produce apparently inconsistent patterns in the aggregate.

Through initial discrete wavelet transforms (DWTs), we observe each series' frequency components and can compare inflation expectations to the consumption and savings trends on a component-by-component basis.

Then, continuous wavelet transforms (CWTs) reveal how the underlying periodic oscillations interact and compete amongst each other over time to produce each aggregate time series. In particular, we find that periods of crisis correlate with time intervals of greater explanatory power for each series in terms of their logarithmic difference.

With these CWTs, we can next analyze the co-movement and, thus, relationship between expectations and consumption and savings through cross-wavelet transforms (XWTs) of the logarithmic differences. Through the resulting power spectra, we identify not only the spikes in co-movement during times of economic turmoil and in high-frequency ranges, but we also uncover the phase difference between each combination. This phase difference allows us to relate these patterns back to the concept first highlighted regarding cyclicity in Figure 19, in which we first see how phase difference between two cyclical series can impact our interpretation of their relationship in the time domain. By extracting and visualizing this additional information, we establish objective indicators to show from where the inconsistency in the aggregate relationships may originally arise.

Finally, we conduct a time scale regression using the frequency components generated by the DWTs to quantify the relationship between inflation expectations and consumption and savings at each cyclical period. These results provide clear evidence of the positive, Euler-consistent relationship between inflation expectations and nondurables. But perhaps more crucially, the regressions on durables consumption and savings offer explanations as to how their relationships with inflation expectations have seemed so inconsistent at the aggregate level. Essentially, the time scale regressions suggest that durables and savings may relate in an Euler-consistent manner at the business cycle-range of frequencies but in a precautionary manner at both higher and lower frequency ranges than this range.

The decision to analyze the relationships through the series' logarithmic differences allows us to observe the impact of changes in inflation expectations on the behavioral patterns, but interpreting the results is admittedly less intuitive. The additional wavelet analysis we conduct using the more "headline" format or percentages—the direct inflation rate expected and the percentage change in consumption and savings—provides a means to connect the results back to the original data and existing literature. As we see, the results in percentage terms appear in line with our benchmark model by Coibion et al. (2021). Further, the corresponding CWT and XWT power spectra (in Appendix C.2. Continuous wavelet transforms of series in percentage terms and Appendix C.3. Cross-wavelet transforms of series in percentage terms respectively) show that the relationships in these headline terms have higher power at lower frequencies and that they maintain greater consistency in their phase differences. This is an interesting distinction and may suggest that while the sensitivity of these relationship (i.e. logarithmic difference), and especially that of their inflation expectations, may have greater power at higher frequencies, the more headline format—more present in our daily lives—may adhere more to the larger cyclical periods.

Indeed, this distinction between the logarithmic and headline results also connects to the difference in roles that qualitative and quantitative inflation expectations play in consumption and savings decisions uncovered in Chapter 2. Just as qualitative estimates are a better predictor of short-term decisions in the Savings Game than quantitative estimates, the logarithmic differences in expectations (i.e. our proxy for macro-level qualitative estimates) exhibit a stronger relationship with consumption and savings at shorter cycles. Further, the positive relationship identified in our present analysis between expectations and nondurables consumption is also consistent with the positive relationship identified in Chapter 2.

Naturally, there are points of contention with our approach. One key point is that we only investigate households' inflation expectations on their consumption and savings behavior, ignoring all other variables. Incorporating other variables offers an intriguing direction to take this research. Income-related variables, such as personal income or even gross domestic product and/or gross national product, certainly contribute to households' decision-making. But, this mechanism too could depend on how households perceive and anticipate inflation as well as vary at different time-cycle horizons. Interest rates offer another key variable from the perspective of both savings incentive as well as the cost of borrowing for durables (or even nondurables) consumption.

Another point is that we apply essentially no data processing, cleaning, normalizing, or detrending. This is intentional so as to test wavelet's ability to inherently bring clarity to noisy data, which our results generally suggest that the technique does.

Being so, one might also argue that these results could be potentially biased by the use of nominal consumption and savings data. As a result of the nominal data, the analyses could overstate the relationships with inflation expectations since expectations correlate quite strongly with headline inflation (Bignon & Gautier, 2022; Reiche & Meyler, 2022; Weber, Gorodnichenko, et al., 2023). In other words, inflation increases both expectations as well as nominal consumption and savings, so this could inherently bias the results. To address this objection, we conduct the same analyses on the series in real terms. Based on the results presented in Appendix C.5. Continuous wavelet transforms of series in real terms, Appendix C.6. Cross-wavelet transforms of series in real terms, and Appendix C.7. Regressions in real terms, no such bias appears evident.[38]

Moreover, our objective in this study is to provide a new perspective to a long-standing and—for better or worse—recently revived economic conundrum. Through this new perspective, we find that changes in inflation expectations demonstrate the clearest relationship to consumption and savings behaviors during times of higher inflation as

[38] I use constant 2017 US dollars.

well as economic turmoil, particularly in shorter cyclical periods. This finding suggests that inflation expectations as an indicator may, therefore, be most important as inflationary periods and economic crises unfold. Such results seem consistent with the literature on inflation expectations and attention, whereby consumers pay greater attention to information on inflation when in a high-inflation environment (Cavallo et al., 2017; Weber, Candia, et al., 2023).

Furthermore, through time scale regression, this new perspective that wavelet analysis affords us offers quantitative evidence of the differing relationships with each behavioral series across time-cycle horizons, which can produce seemingly inconsistent patterns in the aggregate. Specifically, while inflation expectations and nondurables consumption exhibit Euler-consistent behavior across all cycles, durables and savings appear Euler-consistent within the business-cycle range of cyclical periods but demonstrate precautionary behavior at shorter and longer terms. This shift in behavioral model at the business-cycle range is notable, given that many durables are purchased at a two- to eight-year cycle, meaning that at shorter time-cycle horizons, households may focus more on nondurables and savings.

With this quantitative evidence, we can more clearly reason about how consumption and savings patterns may proceed in relation to inflation expectations as inflationary conditions ease in the United States. Particularly, if inflation, and thus expectations, continues to decrease, we may expect to see a slowing of nondurables consumption and shift to both durables and savings in the short-term, with households ultimately growing their savings over the course of the longer-term business cycle. We may also expect that in the aggregate, these patterns may not be immediately obvious.

Conclusion

The preceding three chapters share the primary objective of understanding how economic agents—primarily household consumers—behave when faced with inflation. As I mention throughout the preceding chapters, the existing literature has provided inconsistent results when analyzing the relationship between inflation expectations and consumer behavior; this is the case from the theoretical perspective as well as empirical. Therefore, I develop and apply novel techniques in order to provide new perspectives both at the micro- and macroeconomic levels, and ultimately a clearer understanding of the relationship's underlying complexity.

Research investigating the inflation-consumption relationship has typically employed survey-based, macroeconomic approaches, so my first aim is to provide micro-level data that can directly connect how consumers internalize (i.e. perceive and anticipate) inflation with regard to their subsequent savings and consumption decisions. To do so, I turn to experimental economics. I develop an experimental task, the Savings Game, that places subjects in a controlled environment through which we can adjust inflationary conditions to observe how subjects internalize and ultimately react to price changes by adapting their consumption and savings decisions, or not. Within experimental economics, this work contributes an easily implementable task to simulate inflation in the laboratory—or online. The codebase developed for the Savings Game task is freely available for use at https://github.com/o-nate/savings-game and may be freely tested and explored at https://savingsgame.org.

Through our first experiment, we find that subjects perform poorly on average when faced with inflation and that the more inflation varies, the worse they perform. Moreover, subjects' performance depends on the accuracy of their inflation perceptions and expectations. We also observe a strong heterogeneity among subject performances, which correlates solidly to unique individual characteristics, particularly numerical abilities and consistency of economic decision-making. Finally, in testing an intervention, we find essentially no impact by traditional financial education techniques on in-task performance. Furthermore, beyond these findings, we also demonstrate the Savings Game's external validity, whereby subjects' exhibit similar biases in-task as in real life.

This demonstrated external validity allows us to gain an initial sense of how consumers' internalization of inflation may relate to their macroeconomically measurable savings and consumption behavior. Nevertheless, the external validity of our first experiment does not provide a direct link between the in-task measures of inflation internalization and the survey methods employed at the macro-level in real life. Further, our initial experiment lacks a critical first data point of subjects' inflation expectations that impedes our attempt to understand their high levels of purchasing in the early phases of the task. Accordingly, we modify the Savings Game and design a new experiment to extend the external validity directly to the survey-elicited data used in the macroeconomic literature and to fill this missing data point on early-purchase behavior.

With these refinements, our second experiment's results suggest that higher inflation expectations do indeed relate to higher consumption levels—Euler-consistent behavior—as well as that the qualitative data that survey methods produce may provide better predictors of behavior. Additionally, we find that the uncertainty of subjects' inflation internalization is, itself, a relevant indicator. This discovery ties in more generally to the persistent stylized facts within the existing literature on the biases in consumers' inflation internalization (Andrade et al., 2023; Binder, 2017; Reiche & Meyler, 2022). Moreover, the results we find across both experiments—that numerical abilities and consistency in economic decision-making relate strongly to performance level—also add evidence. In fact, like Armantier et al. (2015), who find that subjects in their experiment with lower numeracy and financial literacy perform worse, our experimental results offer additional evidence supporting the idea that:

> the direct effect of cognitive abilities on the accuracy of inflation expectations feeds into actual and planned consumption and saving choices, because high-IQ

> individuals behave in line with the consumer Euler equation, whereas those below the median of the population by IQ, even when not facing any financial or liquidity constraints, do not behave in line with any standard model of intertemporal consumption optimization. (D'Acunto et al., 2022)

Ultimately, this connection between cognitive abilities and consumption optimization in inflationary conditions may imply that there is, indeed, a significant heterogeneity in the relationship between inflation and behavior at the micro-level across not only inflationary conditions (i.e. the magnitude and degree of variance of price changes), but also individuals. As such, this heterogeneity may subsequently produce an unclear relationship at the macro-level. Therefore, to address this possibility, I then turn to the macroeconomic data to understand this inconsistency.

Beyond the heterogeneity of individuals, which the literature has already studied extensively, I apply wavelet analysis to additionally explore the cyclical nature underlying the relationship between US inflation expectations and consumption and savings behavior at the macroeconomic level. Through this work, I aim in part simply to demonstrate the possibilities and novel perspectives that wavelet analysis offers; the code developed for this analysis is freely available for use at https://github.com/o-nate/inflation-wavelets. Moreover, my objective is to find parallels between our experimental and real-life data. The wavelet analysis reveals a clear positive relationship between inflation expectations and nondurables consumption—Euler-consistent behavior—across all cyclical periods. This result, in particular, provides a bridge to our experimental results, where in-task consumption too can be considered as nondurable, suggesting that we can in fact observe such parallels between behavior in the Savings Game and in real-life macroeconomic data. Further, my wavelet approach uncovers evidence that the inconsistent results and patterns observed in the literature are, rather, reflections of not only the phenomena's underlying cyclical natures, but also the validity of both the Euler consumption and precautionary savings (i.e. wealth effect) models in describing households' behavior.

Moving forward, this work offers some helpful lessons for both further research and the direction of monetary policy. For research, the possible coexistence of Euler-consistent and precautionary models requires resolving and poses interesting research questions for experimental economics. Particularly, studying the circumstances under which consumers shift from Euler-consistent to precautionary behavior as well as how individual characteristics, like cognitive abilities, relate to this shifting appears an interesting direction. From the monetary-policy perspective, awareness of this coexistence can help central bankers with predictive modeling. As the wavelet analysis demonstrates, not only is there evidence supporting both the Euler-consistent and precautionary models, but these relationships depend on the time-cycle horizon considered as well as the type of behavior. Whereas nondurables consumption appears strictly Euler-consistent, durables consumption and savings behavior exhibit both patterns, which in the aggregate may appear simply as inconsistent. With this new frequency-based perspective, central banks can better predict how short- and long-term outcomes may relate.

Additionally, the Savings Game task itself presents a number of research questions to investigate. These include studying new variations, such as adding multiple goods; offering credit options; testing new inflation sequences; and perhaps most interesting, including a monetary policy component that varies the interest rate as inflation progresses. Another area of research within the Savings Game is the effect of and the ways in which individuals use the information available to them. For instance, studying the effect of displaying the real interest rate or even requiring that subjects click to reveal information as a means of tracking what information they actively seek and utilize.

For central bankers, this work also further confirms, if not adds greater priority to, keeping the public informed of the inflation rate as well as communicating on the real interest rate—not just the nominal one—thereby encouraging individuals to think in real, rather than nominal, terms. Beyond information and, thus, anchoring, though, central bankers might also take note that more than just financial literacy plays a role in household consumers’ abilities to appropriately react to inflation; in fact, numerical abilities may play a more critical role ultimately. Numeracy's importance, however, may pose a greater challenge than financial literacy since people are primarily likely to gain numerical abilities early in life.

Finally, though, this challenge presents another area in which the work presented herein provides helpful lessons. As noted through the preceding chapters as well, inflation can pose grave financial risk to households, and finding effective methods to help them protect themselves from the threat of rising prices is paramount. For this reason, our experiments go beyond just studying consumers' behavior and test interventions to actually help them improve their decision-making. We demonstrate how interventions must not only keep consumers informed about inflation and explain how to handle inflationary conditions, but also provide them with feedback regarding the impact on their financial situations of their personal consumption and savings decisions. While this may seem overly personalized for mass-distributed financial education material, the fact is that consumers' financial lives are becoming increasingly digitalized. This transition, in fact, offers many opportunities to develop and provide large-scale yet dynamic and personalized education and support to households.

Hopefully, my research's findings on both the relationship between household consumers' behavior and inflation as well as the components of effective educational interventions to protect them against inflation can provide a foundation for the development of such support.

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Appendix A.
Supplemental material: Chapter 1

Appendix A.1. Additional results

Appendix A Table 1 - Purchase adaptation at each inflation phase-change

	Inflation sequence											
	4x30			10x12								
Period	**33**	**63**	**93**	**15**	**27**	**39**	**51**	**63**	**75**	**87**	**99**	**111**
Mean difference	1.38***	0.2	0.22*	1.36	0.09	1.21***	-0.11	0.08	0.36***	0.07	0.2***	-0.01
(std)	(4.13)	(1.86)	(1.17)	(7.38)	(3.44)	(4.56)	(2.83)	(1.06)	(1.55)	(1.53)	(1.02)	(0.92)

Appendix A Table 2 - Correlations between performance measures and inflation sequences

	Purchase adaptation 10x12	Purchase adaptation 4x30	Over-stock (%) 10x12	Over-stock (%) 4x30	Wasteful-stock (%) 10x12	Wasteful-stock (%) 4x30	Under-stock (%) 10x12	Under-stock (%) 4x30	Final savings (%) 10x12	Final savings (%) 4x30
Purchase adaptation 10x12	—									
Purchase adaptation 4x30	0.28***	—								
Over-stock (%) 10x12	-0.2**	-0.11	—							
Over-stock (%) 4x30	0.02	-0.3***	0.04	—						
Wasteful-stock (%) 10x12	-0.07	-0.16	-0.12	0.09	—					
Wasteful-stock (%) 4x30	-0.12	-0.06	0.02	-0.15	0.52***	—				
Under-stock (%) 10x12	-0.16	0.03	-0.71***	-0.21**	-0.06	-0.03	—			
Under-stock (%) 4x30	-0.06	0.01	-0.18*	-0.7***	-0.15	-0.06	0.37***	—		
Final savings (%) 10x12	0.41***	0.13	0.19*	0.2**	-0.37***	-0.27***	-0.72***	-0.25***	—	
Final savings (%) 4x30	0.11	0.37***	0.06	-0.56***	-0.43***	-0.61***	0.03	0.2**	0.16	—

Appendix A Table 3 - Results of economic preference tasks

	Mean	**Standard Deviation**
WCST, number correct	15.52	7.08
Risk aversion, safe choices	6.12	2.14
Risk aversion, number of switches (Correct number)	1.27 (1)	1.09
Loss aversion, coin tosses	2.15	1.36
Loss aversion, switches (Correct number)	1.09 (1)	0.67
BRET, total boxes collected	47.24	24.30
Time preferences, smaller-sooner choices	10.96	6.41
Time preferences, switches (Correct number)	3.23 (3)	1.44

Appendix A Table 4 - Responses to real-life inflation behavioral changes

	Increase (%)	**No change (%)**	**Decrease (%)**
Purchase of cheaper goods	64.90	31.73	3.37
Purchase of goods less impacted by inflated	53.37	45.19	1.44
Quantity purchased	8.17	52.40	39.42
Stock Maintained	26.92	46.15	26.92
Spending on leisure	4.33	32.69	62.98
Spending on subscriptions	4.81	48.56	46.63
Investment in insurance	12.50	71.15	16.35
Investment in real estate	13.94	69.71	16.35
Investment in Livret A	34.62	43.27	22.12
Investment in mutual funds	6.73	75.00	18.27
Investment in stocks	9.62	68.75	21.63
Investment in indexed bonds	10.10	68.75	21.15
Money held in checking account	11.06	59.62	29.33

Appendix A Table 5 - Responses to real-life inflation behavioral changes, yes-no

	Yes (%)	**Maybe (%)**	**No (%)**
Move to lower rent	9.62	25.00	65.38
Seek additional income	71.15	18.27	10.58
Seek a new job	29.33	18.75	51.92
Reduce energy consumption	35.58	25.48	38.94
Change mode of transportation	45.19	18.75	36.06

Appendix A Table 6 - Real-life perceived and expected inflation

	Mean (%)	**Standard deviation**	**Minimum**	**50%**	**Maximum**	***Headline inflation***
Highest inflation in last 30 years	17.04	17.54	-34.90	11.50	100.00	*6.30*
Lowest inflation in last 30 years	0.16	13.02	-85.30	0.60	95.60	*0.00*
Average perceived inflation for last 12 periods	13.46	14.31	-17.80	9.32	87.85	*6.00*[a]
Perceived current inflation	9.51	11.83	0.00	6.50	96.10	*6.00*[b]
Expected inflation for next 12 periods	14.07	16.38	0.00	9.25	98.20	*2.90*[c]

[a] February 2023
[b] February 2023
[c] February 2024

Appendix A Table 7 - OLS regression of performance on intervention and inflation measures

Variables	(1) Final savings (%)	(2) Over-stock (%)	(3) Wasteful-stock (%)
Intercept	0.4346***	0.3074***	0.1422***
	(0.0487)	(0.0488)	(0.0314)
Inflation, 10x12	-0.1843***	-0.0870	-0.0217
	(0.0599)	(0.0600)	(0.0386)
Day 2	-0.0930	0.1631***	0.0060
	(0.0593)	(0.0594)	(0.0382)
Day 3	-0.0226	0.0942	-0.0128
	(0.0645)	(0.0647)	(0.0416)
Day 4	-0.0499	0.1363**	-0.0053
	(0.0592)	(0.0594)	(0.0382)
Treatment, Intervention	-0.0518	-0.0649	0.0860**
	(0.0624)	(0.0625)	(0.0402)
Inflation, 10x12 × Day 2	0.1457*	-0.0050	-0.0318
	(0.0840)	(0.0842)	(0.0541)
Inflation, 10x12 × Day 3	0.0854	0.0818	-0.0091
	(0.0848)	(0.0850)	(0.0547)
Inflation, 10x12 × Day 4	0.1179	-0.0796	-0.0172
	(0.0845)	(0.0847)	(0.0545)
Inflation, 10x12 × Treatment, Intervention	0.0166	0.0532	-0.0614
	(0.0838)	(0.0840)	(0.0540)
Day 2 × Treatment, Intervention	0.0522	0.0654	-0.0966*
	(0.0836)	(0.0838)	(0.0538)
Day 3 × Treatment, Intervention	0.1033	0.0057	-0.0859
	(0.0868)	(0.0870)	(0.0559)
Day 4 × Treatment, Intervention	0.0230	0.0574	-0.0806
	(0.0857)	(0.0859)	(0.0552)
Inflation, 10x12 × Day 2 × Treatment, Intervention	0.0458	-0.1499	0.0598
	(0.1178)	(0.1181)	(0.0759)
Inflation, 10x12 × Day 3 × Treatment, Intervention	-0.0750	-0.0902	0.1123
	(0.1188)	(0.1190)	(0.0765)
Inflation, 10x12 × Day 4 × Treatment, Intervention	0.0626	-0.0590	0.0708
	(0.1191)	(0.1194)	(0.0767)
Expectation sensitivity	0.0204	-0.0428	-0.0052
	(0.0287)	(0.0288)	(0.0185)
Expectation bias	0.0012*	-0.0011	0.0001
	(0.0007)	(0.0007)	(0.0004)
Perception sensitivity	0.1820***	-0.1112***	-0.1296***
	(0.0342)	(0.0343)	(0.0221)
Perception bias	-0.0003	0.0007*	-0.0001
	(0.0004)	(0.0004)	(0.0003)

R-squared	0.1700	0.1663	0.1201
R-squared Adj.	0.1299	0.1259	0.0776

Standard errors in parentheses.

* p<.1, ** p<.05, *** p<.01

Appendix A Table 8 - Forward-selected OLS regressions of change in performance measures on intervention and individual characteristics

Variables	**(1) Final savings (%)**	**(2) Over-stock (%)**	**(3) Wasteful-stock (%)**
Intercept	-0.3117	0.9420***	0.1018
	(0.1942)	(0.2073)	(0.1538)
BRET, total boxes collected		-0.0034**	
		(0.0015)	
Financially literate			-0.0580
			(0.0439)
Treatment, Intervention	-0.2862	-0.0221	-0.0832
	(0.1737)	(0.1081)	(0.1201)
Treatment, Control × Compound		-0.0921	
		(0.1026)	
Treatment, Control × Total switches			-0.0319*
			(0.0187)
Treatment, Control × WCST, number correct	-0.0020		
	(0.0071)		
Treatment, Intervention × Compound		-0.1398	
		(0.1284)	
Treatment, Intervention × Total switches			-0.0185*
			(0.0107)
Treatment, Intervention × WCST, number correct	0.0177**		
	(0.0074)		
Numerate		-0.1820*	0.1034**
		(0.0978)	(0.0494)
Wage quartile, 1		-0.1811*	
		(0.0979)	
Wage quartile, 2		-0.0673	
		(0.0968)	
Wage quartile, 3		-0.0709	
		(0.0971)	
Change in expectation bias		-0.0044*	
		(0.0024)	
Change in perception bias		0.0050***	
		(0.0018)	
Education level	0.0777	-0.0657	-0.0369
	(0.0487)	(0.0505)	(0.0266)
Can save in real life			0.0949*
			(0.0544)
Total switches	0.0234	-0.0176	
	(0.0165)	(0.0166)	
Risk aversion, safe choices		-0.0433**	0.0107

		(0.0169)	(0.0096)
Time preferences, smaller-sooner choices	0.0077		
	(0.0056)		
R-squared	0.1323	0.3534	0.1636
R-squared Adj.	0.0786	0.2600	0.0932

Standard errors in parentheses.

* p<.1, ** p<.05, *** p<.01

Appendix A.2. Savings Game instructions[d]

Instructions: Savings Game

We will now explain the Savings Game on the following pages. As mentioned before, you will complete play the game four times over the course of four days.

On the following pages, we will explain how the Savings Game works.

Comprehension and Practice Questions

As you go through the instructions on the following pages, we will ask you questions or have you perform certain tasks related to the Savings Game to confirm you understand the game's mechanics and rules.

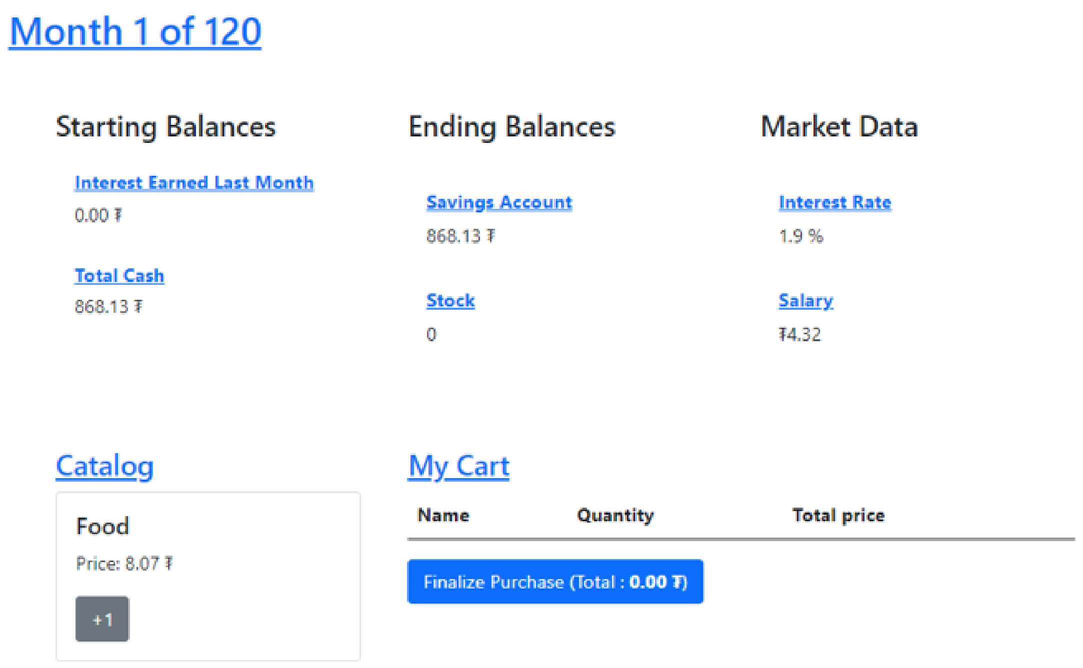
When you are ready to proceed, please click the Next below.

Game Screen

First, we will explain the game's mechanics. Then, we will explain the rules of the Savings Game.

The below is an example of the primary screen you will see and interact with during the Savings Game. On the next page, we explain each component of this screen.

[d] For a hands-on demo of the Savings Game instructions, visit https://savingsgame.org/demo/instructions.



Appendix A Figure 1 - Instructions interface, guide for on-screen information (a pop-up messag appears when the blue titles are clicked with an explanation)

Game Screen

In this example of the primary game screen, certain titles are underlined with blue text. Click the titles in blue to learn what each component is.

*Once you have understood all components, practice using the screen by **adding 4 units** of Food to My Cart and click Finalize Purchase to proceed.*

<u>Month 1 of 120</u>

- Here you see how many months remain in the Savings Game. It last 120 Months in total.

Starting Balances

<u>Interest Earned Last Month</u>

- This shows how much interest you earned on your Savings Account in the previous month.

Total Cash

- Total Cash is how much money you have to spend each month on Food.

Ending Balances

Savings Account

- This shows you how much money you will keep for the next month after clicking Finalize Purchase at the bottom. It is also how much you will earn interest on.

Stock

- Here, you see how much Food you will have this month.

Catalog

- Catalog displays the current price of Food. To add units of Food to My Cart, click the grey +1 button as many times as needed.

Food

Price

My Cart

- My Cart shows you the Quantity of Food you have selected and the Total Price you will pay.

Name

Quantity

Total price

Finalize Purchase (Total:)

Game Screen

Ending Balance

As you adjust the Quantity of Food in My Cart, the values in Savings Account and Stock change. This helps you plan for the future.

Now, adjust the Quantity in My Cart so that the value in Savings Account is **851,99 ₮** and click Finalize Purchase to proceed.

Note: To **reduce the Quantity** in My Cart, click the grey button labelled "-1".

Game Screen

Now, adjust the quantity in your cart so that your Stock has **1 unit** of Food and then click Finalize Purchase.

Rules of the Savings Game

Now that you understand how to operate the game screen, we will explain the rules of the Savings Game.

Remuneration

As mentioned in the Introduction, you will receive additional study remuneration based on your performance in the Savings Game.

Your performance is based on the final value in your Savings Account at the end of the game (after 120 months). After completing the four rounds of the Savings Game (each 120 months) over the four days, a computer program will randomly select one of your rounds' and its corresponding final Savings Account result.

It will convert this amount to Euros (€) and add this value to your participation fee.

Conversion

The game's currency is denominated by **₮**. There is a conversion rate of: **823₮ = 1€**. This means that if the selected round's Savings Account value is 8230₮, you will receive an additional 10€.

Comprehension Question

The final value of which of these balances determines your performance-based remuneration for the Savings Game?

- Stock
- Interest earned
- Savings Account
- Total Cash

Survival

To survive from one month to the next, you must **eat one unit of Food each month**. The minimum amount you must have in your Stock to survive to the next month is 1. If during the Savings Game you end a month when your Stock value is 0, you die, and the game ends.

Every month, you have the option to buy Food at the price listed in the Catalog.

Since you only eat 1 unit of Food per month, any additional units you purchase in a month are saved in Stock. If you have Food in Stock, you are not obligated to buy any more.

Adding the current month number and the Stock value tells you until what month you can survive. For example, if in Month 7, you have 3 units, you will survive until Month 10.

Remuneration

Note: If the game ends because you are unable to end the month with your Stock equal to **1 or more**, the final amount of your Savings Account recorded for that day will be 0₮.

But, you can still earn additional remuneration for that day by answering follow-up questions and completing the day's supplementary tasks or questionnaires.

You also still have three other rounds to increase your remuneration.

Comprehension Question

What is the minimum amount you must have in your Stock before clicking the "Finalize Purchase" button to survive to the next month?

- 120
- 3
- 1
- 0

Interest Earned Last Period

You earn interest the following month on the amount in Savings Account when you click Finalize Purchase. The higher the amount of money in Savings Account, the more money you will earn in interest. At the start of a new month, the Interest Earned Last Month is added to your Total Cash.

The interest rate remains the same throughout the Savings Game.

For example, if a game's interest rate is 1,9% and the value in Savings Account is 868,13 ₮, the player will earn 16,47 ₮ the following month (868,13 ₮ X 0,019).

Comprehension Question

Can the interest rate change during the Savings Game?

- No
- It depends how much is in Total Cash
- Yes
- It depends how much is in Savings Account

Salary

In addition to the interest you may earn on your Savings Account, every month you automatically receive a monthly salary of 4,32 ₮. This amount is added to your Total Cash.

Total Cash

Total Cash is the sum of your previous Savings Account balance, the Interest Earned Last Month, and your monthly salary.

Comprehension

Suppose a player had 100₮ in Savings Account last month. If they earn 10₮ in interest and receive 20₮ in monthly salary, what will their Total Cash be?

- 130,00 ₮
- 120,00 ₮
- We do not have sufficient information to determine.
- 100,00 ₮
- 110,00 ₮

Follow-up Questions

Over the course of the Savings Game, you will be asked questions that relate to your experience.

Choice Confidence

Occasionally, after you finalize a purchase decision, you will be asked to rate how confident you feel about that decision on a scale from 1 to 5.

1 means you feel "Not at all confident to have made the right decision." 5 means you feel "Absolutely confident to have made the right decision."

Now, try answering a choice confidence question. Select the value that would reflect that you feel **completely indifferent** about your decision (i.e. neither confident nor unconfident).

How confident are you that you made the right decision this month?

- 1 – Not at all confident to have made the right decision
- 2
- 3
- 4
- 5 – Absolutely confident to have made the right decision

Follow-up Questions

Price Change Percentage Estimates

Also, every 12 months, you will be asked to estimate by what percentage (%) you think the price of **Food** changed during the previous 12 months. To make an estimation, you must select the desired value using a "slider" -- the blue bar shown below.

You will receive **493,80 ₮** for each of these questions that you answer correctly to within 3% (e.g. if the answer is 50% and you estimate any value between 47% and 53%, you earn an additional 493,80 ₮).

Note: This is meant to be simply your best guess, so you will have 10 seconds to respond.

Now, try using the slider below to select the value: **1%**. When you are done, click the "Next" button below it.

Click the blue bar to reveal the slider. Drag it along the bar to select your estimate.

Appendix A Figure 2 - Practice slider

Congratulations, you have completed the Savings Game Instructions and passed the comprehension test. We will now begin the Savings Game. Click the Next button below when you are ready to proceed.

Appendix A.3. Intervention[e]

The simple financial education is provided below. Note that after receiving the guidance, subjects complete a series of comprehension questions that present different combinations of inflation and interest rate and stock as in-task simulations and ask them:

1. whether they can buy more, less, or the same amount of the good as before and
2. what they should do in the presented situation (save, buy one unit, or buy more than one unit).

Explanation: Optimal Strategy

For the remaining two rounds of the game, we will explain the optimal strategy to maximize your final Savings Account balance.

Comprehension Questions

You must also answer some questions to confirm you understand the new information.

Click the Next button below to proceed.

Maximizing Your Final Savings Account Balance

Maximizing the final balance of your Savings Account during requires a strategy to minimize the cost of the 121 units of Food that you must buy during the game.

Inflation Rate

In the game, the Inflation Rate corresponds to the rise in the price of Food. Depending on your expectations of inflations, it may be that you must buy more in advance to avoid paying more for Food later.

Interest Rate

[e] For hands-on demo of the intervention, visit https://savingsgame.org/demo/intervention.

At the end of each month, the balance in your Savings Account increases by 1.9% thanks to the Interest Rate. But, if next month's Inflation Rate is greater than the Interest Rate, you will not be able to buy as much Food in the next month as now.

Comprehension

The Inflation Rate is related to:

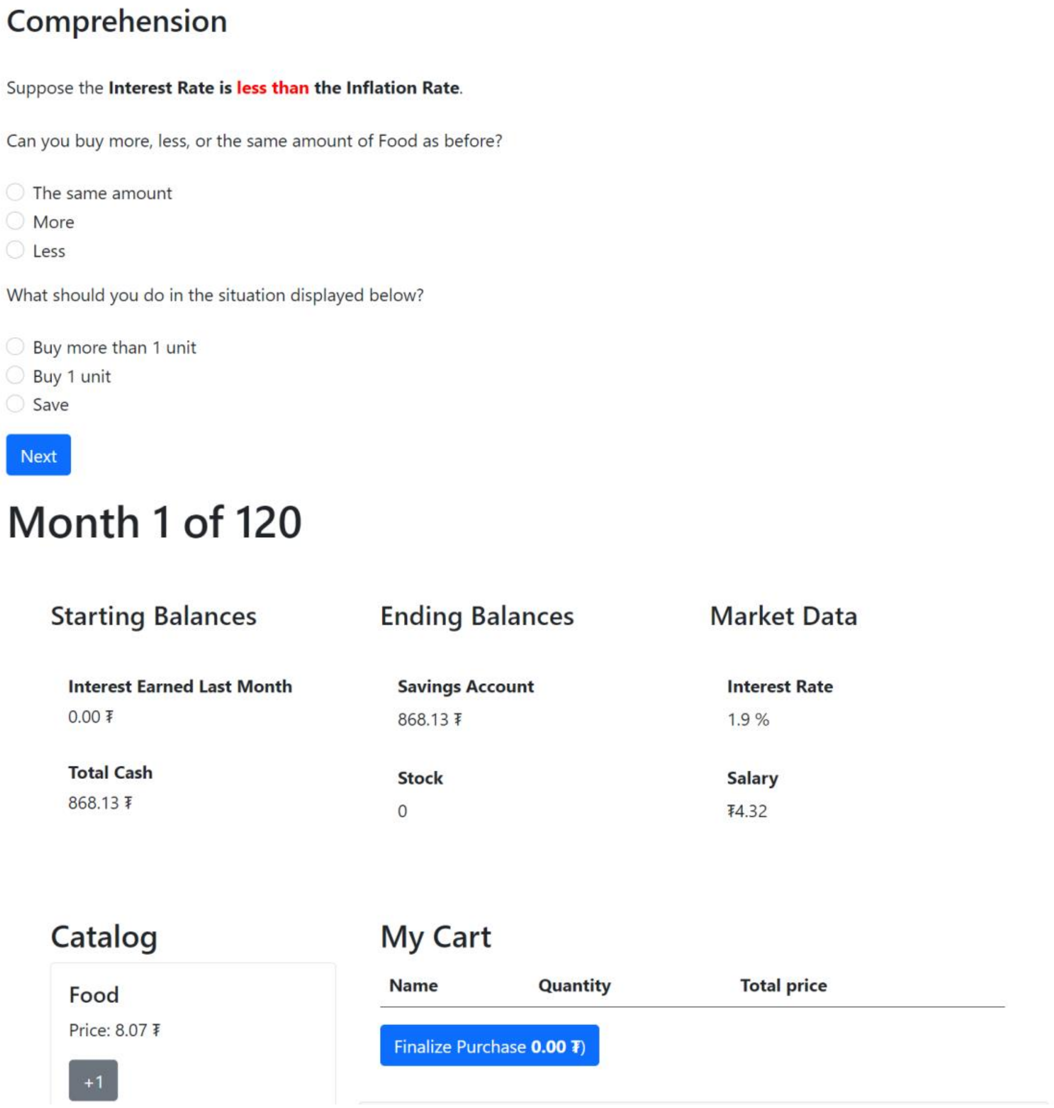
- An increase in the price of Food
- Interest Rate
- None of the above
- An increase in Salary

The Optimal Strategy

To buy at the lowest cost and maximize your final balance, you must buy **only 1 unit** of Food per month when the **Interest Rate is greater than the Inflation Rate**.

When **the Interest Rate is less than Inflation Rate**, you must **stock up** on Food so that you do not need to buy it at the higher price later.

The quantity you buy should be sufficient to create a Stock equal to the number of months you expect to Inflation Rate to be greater than the Interest Rate.



Appendix A Figure 3 - Example of comprehension question

Appendix A.4. Opportunity cost calculation

As explained in the intervention, the best strategy is to save money when $r > \pi_t$ and, as soon as $r < \pi_t$, stock up sufficient units of the good to survive until the end. Being the case, achieving the maximum final savings account balances in the 4x30 and 10x12 sequences requires buying one unit of the good per day until periods 31 and 13 respectively and then buying 90 and 108 units of the good respectively all at once. Divergences from this maximum possible savings, therefore, result from three types of purchase errors: over-, under-, and wasteful-stocking. Each of these errors produce an opportunity cost.

When a subject over-stocks, they forgo the interest on the additional money spent; the opportunity cost is equal to the difference between the interest they could have earned by waiting and the money they save by buying at a lower price. Conversely, the opportunity cost of under-stocking is the difference between the interest they would have earned on the money they could have saved by buying at a lower price and the extra interest they earned by saving for longer. The opportunity cost of purchasing unit i of the good in period t can be represented for both over- and under-stocking as:

$$C_i^t = p^t(1+r)^{120-t} - p^{t^*}(1+r)^{120-t^*},$$

where $i \leq 121$ and $t^* = 31$ for the 4x30 sequence and $t^* = 13$ for the 10x12 sequence. Finally, where over- and under-stocking opportunity costs are the difference between interest earned and foregone, the opportunity cost of wasteful-stocking is strictly the total interest foregone by spending money unnecessarily. It can simply be represented, therefore, as:

$$C_i^t = p^t(1+r)^{120-t},$$

where $i > 121$.

Appendix A.5. Additional in-task measures

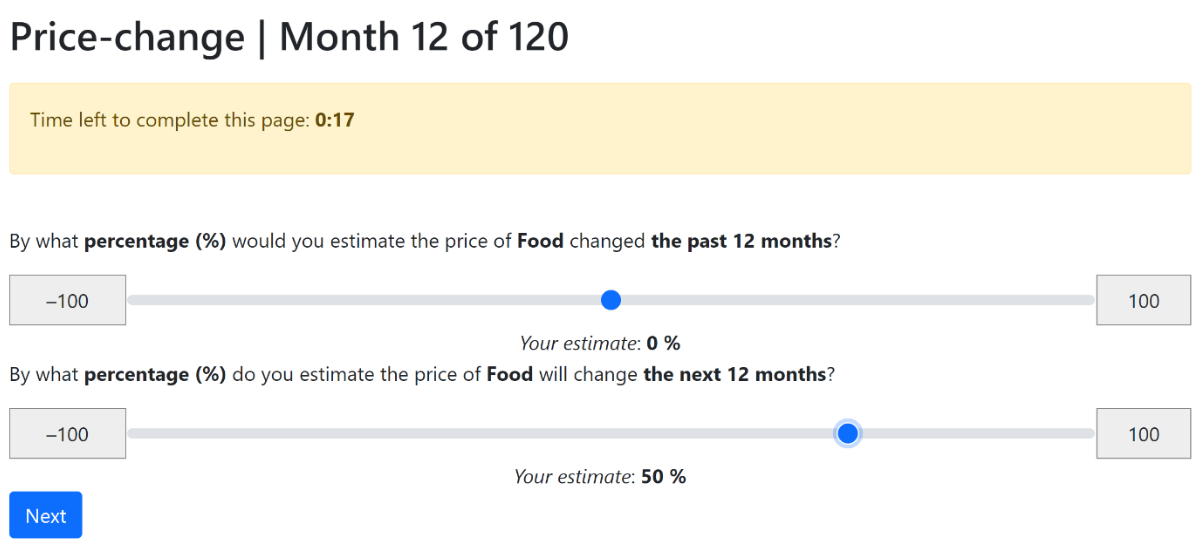
Response impulsivity – Response time

During the consumption simulation, subjects' response time is captured in milliseconds and can be used as a proxy for their response impulsivity, where the faster the response time, the greater the response-impulsivity level (Basar et al., 2010).

Perceived and expected inflation – In-task inflation estimation

Every twelve periods in the Savings Game, we measure subjects' perceived inflation for the preceding twelve periods and expected inflation rate for the next twelve periods. Both measures are elicited through a *slider*, horizontal percentage scale ranging from -100 % to + 100 % in 1% increments as shown in Appendix A Figure 4 below.

Subjects have 30 seconds to provide estimates for inflation rates of both the last and next 12 periods. If they do not click the Next button before the 30 seconds are up, whatever values they currently have selected on the sliders are submitted, and if they do not have values submitted, values of 0% are inputted automatically. We set a time limit to elicit subjects' instinctive estimations, lightly disincentivizing the calculation of the actual percent change



Appendix A Figure 4 - Example of in-task inflation estimation elicitation sliders

Perceived inflation – Post-task inflation estimation

Perceived inflation can be measured as an overall inflation rate estimate via the question "How much do you think prices increased overall?" and compared to the actual average inflation rate during the simulation, as elicited in Georganas et al. (2014).

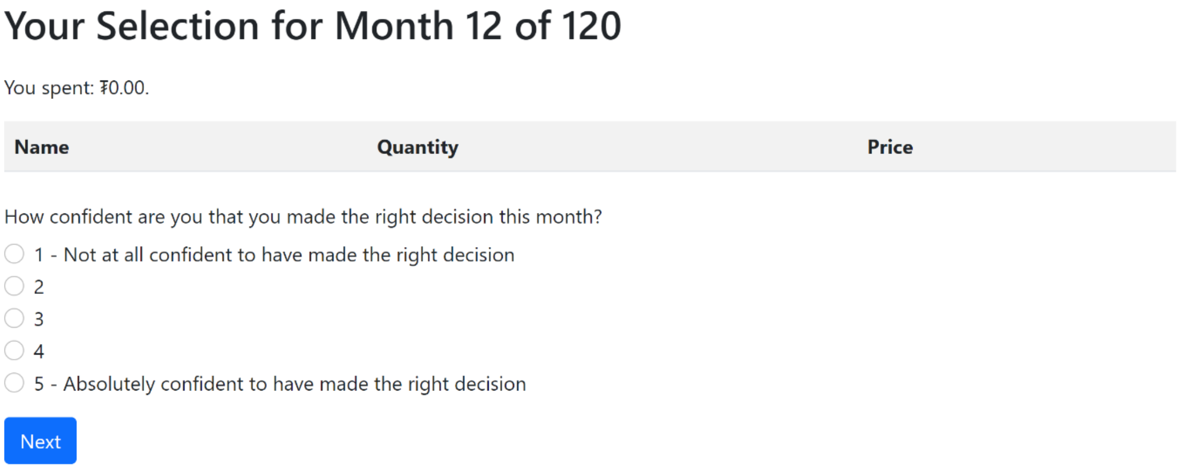
Perceived inflation – Post-task price memory

Perceived inflation can also be measured through inflation estimations of individual goods by asking "How much did the item's price change overall?" and/or "How much did the good cost in the beginning? At the end?" and then calculating a perceived inflation rate based on those data (Georganas et al., 2014).

Choice confidence

After finalizing a purchase decision (either after each decision or on a regular interval), subjects must respond to the questions "How confident are you with your decision?" by selecting an integer from 1 to 5, where 1 indicates "not at all confident" and 5 "absolutely confident" (Fehr & Tyran, 2001). See Appendix A Figure 5.

For both inflation sequences, we elicit choice confidence every twelfth and thirtieth month to coincide with the changes in inflation but obfuscating which sequence subjects face. We also elicit choice confidence the following the month to capture any change in confidence with changes in inflation.



Appendix A Figure 5 - Example of choice confidence elicitation question

Appendix A.6. Knowledge measure questionnaires

Financial literacy

A subject's financial literacy is determined by their correctly responding to the "Big Three" questions from Lusardi and Mitchell (2009). We also include a question on investment product risk categorization from Arrondel and Masson (2014). If a subject fails to answer correctly question 3 of the Big Three but correctly categorizes the investment products' risk, we consider them financially literate.

These questions, with answer choices and correct answer indicated, are:

Question 1

Suppose you had $100 in a savings account and the interest rate was 2% per year. After 5 years, how much do you think you would have in the account if you left the money to grow?

- More than $102**
- Exactly $102
- Less than $102
- Do not know

Question 2

Imagine that the interest rate on your savings account was 1% per year and inflation was 2% per year. After 1 year, how much would you be able to buy with the money in this account?

- More than today
- Exactly the same
- Less than today**
- Do not know

Question 3

It is usually possible to reduce the risk of investing in the stock market by buying a wide range of stocks and shares, true or false?

- True**
- False

Question 4

Below are four financial products. Order them 1 to 4 (from the least risky to the riskiest in your opinion).

Savings account[f]

- 1 – the least risky**
- 2 – the second least risky
- 3 – the second most risky
- 4 – the riskiest

Stocks

- 1 – the least risky
- 2 – the second least risky
- 3 – the second most risky
- 4 – the riskiest**

[f] "Livret A"

Bonds

- 1 – the least risky
- 2 – the second least risky**
- 3 – the second most risky
- 4 – the riskiest

Mutual funds[g]

- 1 – the least risky
- 2 – the second least risky
- 3 – the second most risky**
- 4 – the riskiest

Numeracy

Numeracy is determined through the Berlin Numeracy Test (Cokely et al., 2012), in particular the adaptive version with the questions and respective correct answer listed below. A subject is determined to be numerate if they correctly answer either question 2.b or 3. This means they answer question 1 correctly and move to question 2.b; however, if they miss this second question, they are given question 3 as a follow-up. If they answer question 3 correctly (or 2.b directly), we classify them as numerate.

Question 1

Out of 1,000 people in a small town 500 are members of a choir. Out of these 500 members in the choir 100 are men. Out of the 500 inhabitants that are not in the choir 300 are men. What is the probability that a randomly drawn man is a member of the choir? ________ (%)

- 25

[g] "SICAV/Fond commun de placement (FCP)"

Question 2.a

Imagine we are throwing a five-sided die 50 times. On average, out of these 50 throws how many times would this five-sided die show an odd number (1, 3 or 5)? ______ out of 50 throws.

- 30

Question 2.b

Imagine we are throwing a loaded die (6 sides). The probability that the die shows a 6 is twice as high as the probability of each of the other numbers. On average, out of these 70 throws how many times would the die show the number 6? ________out of 70 throws.

- 20

Question 3

In a forest 20% of mushrooms are red, 50% brown and 30% white. A red mushroom is poisonous with a probability of 20%. A mushroom that is not red is poisonous with a probability of 5%. What is the probability that a poisonous mushroom in the forest is red? ________ (%)

- 50

Compound-interest capability

A subject compound-interest capability is determined through their correctly answering the following questions, with correct answers listed below, from Macchia et al. (2018), where questions 2 and 3 are multiple choice:[h]

[h] We randomize the order of choice options.

Question 1

If inflation is 10% a year, and a product currently costs 1000 €, how much will it cost in one year's time?

- 1100

Question 2

If inflation is 50% a year, and a product currently costs 1000 €, how much will it cost in two years' time?

- Less than 2000
- More than 2000**
- 2000 €

Question 3

If inflation is 3% a year, and a product currently costs 1000 €, how much will it cost in five years' time?

- More than 1150**
- 1150 €
- Less than 1150

Question 4

If inflation is 100% a year, and a product currently costs 1000 €, how much will it cost in five years' time?

- 32000

Appendix A.7. Economic preference tasks

Time preferences

To measure time preferences, we use an intertemporal randomized choice sequence very similar to Cohen et al. (2016). Subjects must complete a binary choice task, whereby they must choose between a series of smaller-sooner and larger-later payouts.

Subjects are presented with three choice tables between a sooner option ("right now") and a later option (one period, six periods, or one year). Each table provides subjects with ten choices (one per row) between the fixed smaller-sooner option of €20 in one column and a larger-later option in the other (ranging from €20 to €200). The ten payment decisions are presented in a randomized order. After completing the table for one of the three possible delays, subjects are presented with the next; the order of delays is also randomized. Time preference is measured by the number of times the smaller-sooner reward was chosen over the larger-later one across the 30 decisions.

Risk preferences

Risk preference is measured in two ways. First, we use the Holt and Laury (2002) lottery choice procedure to elicit risk aversion. Subjects make a series of choices between two lotteries with differing payoff options. The more certain option (A) offers payoffs of either €2.00 and €1.60, while the risky option (B) offers €3.85 and €0.10. Subjects make 10 choices, with the probability of high gains ranging from 10% to 100% by increments of 10%. All the choices are displayed simultaneously and randomly in one table. Afterwards, one of the subjects' 10 lottery choices is randomly selected and played; the resulting payoff is added to their final remuneration. We measure risk aversion by the number of times the certain option is chosen.

Second, we use the bomb risk elicitation task (BRET) by Crosetto and Filippin (2013) using the oTree module developed by Holzmeister and Pfurtscheller (2016). Subjects must collect boxes arranged in an 8x8 matrix that each offers a payoff $\gamma = ₮100.00$. One of the 64 boxes, however, hides a bomb, which if uncovered zeroes all earnings. We measure risk aversion by the number of boxes collected: The greater the number, the greater an individuals' risk tolerance.

Loss aversion

To assess subjects' loss aversion, we conduct a lottery choice task with loss. Subjects are presented a series of risky choices in a table, whereby they must choose between flipping a coin, which offers a payout for tails but incurs cost for heads, and not flipping and thus gaining or losing nothing. In-line with Gächter, Johnson, and Herrmann (2022), we offer subjects six unique lotteries with potential losses ranging from ₮400.00 to ₮1400.00, in increments of ₮200.00, and a fixed potential gain of ₮1200.00. As per expected utility, loss-neutral agents should choose to play lotteries with losses between ₮400.00 and ₮1000.00, whereas loss-averse individuals reject lotteries that present positive expected values. We measure loss aversion as the number of times they choose not to flip the coin.

Wisconsin card sorting task

We assess subjects' adaptability to changing environments through a Wisconsin card sorting task (WCST). Each turn, subjects receive a master card with a unique combination of shape (circle, triangle, plus sign, or star), color (red, yellow, blue, green), and number of shapes (1-4). They also receive a set of four other cards, each with its own unique combination, one of which is a "match" with the master card based on a rule that is not told to the subject (Axelrod et al., 1992; Leshem & Glicksohn, 2007). The subject must guess which card is the match based on having the same shape, color, or number or shapes and is given feedback if they guess correctly or not. After a certain number of correct guesses, the rule changes, and so subjects must recognize this environmental change and discover and readjust to the new rule. The task last 30 turns, and subjects are remunerated ₮50 for each correct guess. We use their total number of correct guesses as a measure of their adaptability.

Preference inconsistency (switches)

Beyond subjects' overall time preferences and risk and loss aversion, we can also measure their choice inconsistency, which provides a proxy for determining an individual's tendency to deviate from economic rationality (Kurtz-David et al., 2019). We calculate this as the number of times the subjects switch between choice options. For time preferences, this means the number of times a subject changes between the smaller-sooner and larger-later options within a single set of delay choices. For risk aversion, this is the number of times they switch from option A to option B lotteries. For loss aversion, this is the number of times subjects switch between flipping and not flipping the coin. In all three tasks, a choice-consistent individual should only switch once per choice set at their point of delay, risk, or loss indifference. Any additional switches result from inconsistent choice behavior.

Appendix B.
Supplemental material: Chapter 2

Appendix B.1. Interventions[i]

Intervention 1

Your performance

We would like to take a moment to reflect on your performance. The maximum that could have been achieved was {{max_performance}}. Your final {{savings_account}} balance was {{performance}}.

You earned {{percent_max}}% of the maximum.

Improving your performance

On the following pages, we will explore how you can improve your performance to maximize your savings.

Comprehension questions

You must also answer some questions to confirm you understand the new information.

Cost of mistakes

The difference between the maximum amount and the amount you earned represents the cost of mistakes during the game. Your cost was XXXX.

[i] For hands-on demos of Intervention 1 and Intervention 2, visit https://savingsgame.org/demo/intervention_1 and https://savingsgame.org/demo/intervention_2 respectively.

There are three mistakes that can occur:

- Stocking up too early
- Not stocking up enough
- Stocking up too much

Timing

Stocking up at the appropriate time requires recognizing when the price of Food is changing by less or more than the interest earned. The interest rate is 1.9%, so if the price of Food increases by more than 1.9% (“high inflation”), you should buy more than one unit of Food. This is because the price of Food is increasing faster than your savings account is accruing interest. Otherwise, you are in low inflation, and your savings account is accruing faster than the price of Food is increasing.

For example, if the price last month was ₮10.00 and the new price is ₮10.30, then the price has increased by 3.0%. This is high inflation. You should buy more than one unit (“stock up”).

But, if the price last month was ₮10.00 and the new price is ₮10.10, then the price has increased by 1.0%. This is low inflation. You should buy one unit.

Comprehension

If the price of Food increased from ₮12.00 to ₮12.12, are you in high or low inflation?

- High
- Low

Stocking too early

This occurs when you buy more than one unit during low inflation. This lowers your savings account balance more than necessary. While you may avoid some price increase, you sacrifice more money to earn interest than you save.

Do you think any of your cost was due to stocking too early?

- Yes
- No
- Maybe

Feedback to responses:

- *Yes*
    - *True*
        - *That is correct. It is important to resist the urge to stock up and sacrifice interest that can be earned. In the future, check whether you are in high or low inflation before stocking up.*
    - *False*
        - *It appears that you did not have any opportunity cost due to stocking too early.*
- *No*
    - *True*
        - *It appears that you did not have any opportunity cost due to stocking too early.*
    - *False*
        - *It appears that you did have opportunity cost due to stocking too early. It is important to resist the urge to stock up and sacrifice interest that can be earned. In the future, check whether you are in high or low inflation before stocking up.*
- *Maybe*
    - *True*
        - *It appears that you did have opportunity cost due to stocking too early. It is important to resist the urge to stock up and sacrifice interest that can be earned. In the future, check whether you are in high or low inflation before stocking up.*

  - *False*
    - *It appears that you did not have any opportunity cost due to stocking too early. It is important to resist the urge to stock up and sacrifice interest that can be earned. In the future, check whether you are in high or low inflation before stocking up.*

Are you convinced that you incurred cost due to stocking too early?

- Yes
- No

Not stocking enough

This occurs when you do not buy enough units in the beginning of high inflation. While you may maintain a higher balance to earn interest, you pay even more for Food than you earn in interest.

Do you think any of your cost was due to not stocking enough?

- Yes
- No
- Maybe

Feedback to responses:

- *Yes*
  - *True*
    - *That is correct. It is important to act decisively when high inflation appears. Remember to pay attention to prices to check whether you are in high or low inflation.*
  - *False*
    - *It appears that you did not have any opportunity cost due to not stocking enough.*
- *No*
  - *True*

        - *It appears that you did not have any opportunity cost due to not stocking enough.*
    - *False*
        - *It appears that you did have opportunity cost due to not stocking enough. It is important to act decisively when high inflation appears. Remember to pay attention to prices to check whether you are in high or low inflation.*
- *Maybe*
    - *True*
        - *It appears that you did have opportunity cost due to not stocking enough. It is important to act decisively when high inflation appears. Remember to pay attention to prices to check whether you are in high or low inflation.*
    - *False*
        - *It appears that you did not have any opportunity cost due to not stocking enough. It is important to act decisively when high inflation appears. Remember to pay attention to prices to check whether you are in high or low inflation.*

Are you convinced that you incurred cost due to not stocking enough?

- Yes
- No

Stocking too much

This occurs when you buy more Food than necessary to survive until the end of the game. You spend more money than necessary and sacrifice interest that money could have earned.

Do you think any of your opportunity cost was due to stocking too much?

- Yes
- No

- Maybe

Feedback to responses:

- *Yes*
    - *True*
        - *That is correct. It is important to pay attention to how much stock you need to survive through Month {{NUM_ROUNDS}}. Your stock should never be greater than {{NUM_ROUNDS}} + 1.*
    - *False*
        - *It appears that you did not have any opportunity cost due to stocking too much.*
- *No*
    - *True*
        - *It appears that you did not have any opportunity cost due to stocking too much.*
    - *False*
        - *It appears that you did have opportunity cost due to stocking too much. It is important to pay attention to how much stock you need to survive through Month {{NUM_ROUNDS}}. Your stock should never be greater than {{NUM_ROUNDS}} + 1.*
- *Maybe*
    - *True*
        - *It appears that you did have opportunity cost due to stocking too much. It is important to pay attention to how much stock you need to survive through Month {{NUM_ROUNDS}}. Your stock should never be greater than {{NUM_ROUNDS}} + 1.*
    - *False*
        - *It appears that you did not have any opportunity cost due to stocking too much.*

Are you convinced that you incurred [no] cost due to stocking too much?

- Yes
- No

Intervention 2

Tips to improve your performance

Let’s take a moment to think about your performance. The maximum performance that could have been achieved is {{max_performance}}. The final balance of your savings account was {{performance}}.

You have gained {{percent_max}}% of the maximum performance.

On the following pages, we’ll explain how you can improve your performance to maximize your earnings.

We’ll ask you a few questions to check your understanding of the advice provided.

Mistakes that reduce performance

The difference between the maximum win and your win comes from several types of purchasing decision errors during the game. Your performance loss is {{max_performance - performance}}.

Three types of mistakes can occur:

- Stocking up too early
- Stocking up too little or too late
- Stocking up too much

We’ll consider the first two first.

The interest rate is 1.9% per month. If the price of food rises by less than 1.9% each month, inflation is lower than the interest rate, and in this case, you don’t need to stock up, you need to buy only the unit of food you need to survive. This is because the interest you accumulate in your savings account rises faster than the price of food, and you gain more by letting your money grow in your savings account than by tying it up in a food stock up. Stocking up on food when inflation is lower than the interest rate is what we call **stocking up too soon**.

Conversely, when the inflation rate is higher than the interest rate, you should stock up (buy more than one unit of food) because the price of food rises faster than the interest accumulated in your savings account. Not stocking up in this situation is what we call **stocking up too little or too late**.

How to identify the inflation phase

To identify the inflation phase, you need to pay attention to the variation in the price of a unit of food and compare it with the interest rate.

To find out whether inflation is higher or lower than the interest rate, we need to track price trends. If last month's price was ₮10.00 and the new price for the current month is ₮10.10, then the price has risen by 1.0%. Inflation is lower. You need to buy only the unit of food you need to survive. If you already have a stock, don't bother buying.

If the price of a unit of food last month was ₮10.00 and the new price is ₮10.30, then the price has risen by 3.0%. Inflation is higher. You should buy more than one unit ("stock up").

Comprehension

If the price of a unit of food has risen from ₮12.00 to ₮12.12, are you in a period of?

- Inflation higher than the 1.9% interest rate
- Inflation lower than the 1.9% interest rate

Why shouldn't we stock up when inflation is low?

When inflation is lower than the interest rate, buying food in advance that you won't consume until later costs you money.

For example, suppose you want to buy ₮10.00 a unit that you won't consume until 12 months later, when inflation over those 12 months will be 1% per month. Instead of buying this unit, it would be better to leave this sum in your savings account.

At the end of 12 months with an interest rate of 1.9% per month (i.e. 25% over 12 months), you have ₮12.50 in your savings account. However, the price of food has only risen by 12.7%. The price is therefore ₮11.27. Buying the unit at this price in 12 months' time gives you a gain of ₮12.50 - ₮11.27 = ₮1.23, which will continue to earn you interest for the remaining time.

To give you an idea of how your savings and prices will evolve over time:

- with an **interest rate** of 1.9% per month, the sum invested doubles after **36 months**
- with an **inflation rate** of 1% per month, the price doubles after **70 months**

Comprehension

Do you think part of your performance loss is due to having stocked up too early?

- Yes
- No
- Maybe

Feedback to responses:

Yes

- *True*
    - *That is correct. It is important to resist the urge to stock up and sacrifice interest that can be earned. In the future, check whether you are in high or low inflation before stocking up.*
- *False*
    - *It appears that you did not have any opportunity cost due to stocking too early.*

No

- *True*
    - *It appears that you did not have any opportunity cost due to stocking too early.*
- *False*
    - *It appears that you did have opportunity cost due to stocking too early. It is important to resist the urge to stock up and sacrifice interest that can be earned. In the future, check whether you are in high or low inflation before stocking up.*

Maybe

- *True*
    - *It appears that you did have opportunity cost due to stocking too early. It is important to resist the urge to stock up and sacrifice interest that can be earned. In the future, check whether you are in high or low inflation before stocking up.*
- *False*
    - *It appears that you did not have any opportunity cost due to stocking too early. It is important to resist the urge to stock up and sacrifice interest that can be earned. In the future, check whether you are in high or low inflation before stocking up.*

Note: The 12-month interest rate is 25% (1.9% per month). If you estimate that the 12-month inflation rate is less than 25%, you should not stock up.

Are you convinced that [you have sustained no losses | you have sustained losses] as a result of stocking up too early?

- Yes
- No

Why should we stock up during a period of high inflation?

When inflation is higher than the interest rate, you lose money by not stocking up on food in advance.

For example, suppose the price of a unit of food is ₮10.00 and you prefer not to anticipate the purchase of the unit you will consume 12 months later when inflation over those 12 months will be 3% per month. You leave ₮10.00 in your savings account, which after 12 months with an interest rate of 1.9% per month, i.e. 25% over 12 months, will become ₮12.50 in your savings account. Now the price of food has risen by 42.6%, and the price is ₮14.26. You're short ₮14.26 - ₮12.50 = ₮1.76, which you'll have to dip into your savings.

To give you an idea of how your savings and prices will evolve over time:

- with an **interest rate** of 1.9% per month, the sum invested doubles after **36 months**
- with **inflation** at 3% per month, the price doubles after **24 months**

Comprehension

Do you think that part of your performance loss is due to stocking up too little or too late?

- Yes
- No
- Maybe

Feedback to responses:

Yes

- *True*
    - *That is correct. It is important to act decisively when high inflation appears. Remember to pay attention to prices to check whether you are in high or low inflation.*
- *False*

  - *It appears that you did not have any opportunity cost due to stocking too little or too late.*

No

- *True*
  - *It appears that you did not have any opportunity cost due to stocking too little or too late.*
- *False*
  - *It appears that you did have opportunity cost due to stocking too little or too late. It is important to act decisively when high inflation appears. Remember to pay attention to prices to check whether you are in high or low inflation.*

Maybe

- *True*
  - *It appears that you did have opportunity cost due to stocking too little or too late. It is important to act decisively when high inflation appears. Remember to pay attention to prices to check whether you are in high or low inflation.*
- *False*
  - *It appears that you did not have any opportunity cost due to stocking too little or too late. It is important to act decisively when high inflation appears. Remember to pay attention to prices to check whether you are in high or low inflation.*

Note: The 12-month interest rate is 25% (1.9% per month). If you estimate that the 12-month inflation rate is higher than 25%, you should store.

Are you convinced that [you incurred no losses OR you did incur losses] due to insufficient or too-late stock?

- Yes

- No

Small mistakes, big losses

The previous two examples may not seem so important to you in terms of losses. But by repeating these mistakes, you can accumulate significant losses.

Now let’s look at the third possible mistake: stocking up too much.

This happens when you buy more units of food than you need to survive to the end of the game. You spend more than you need to and sacrifice the interest your savings could have earned.

If you’re in month T, the total amount of food you’ll need to survive is 121 - T. It’s unnecessary and costly to stock up more.

Comprehension

Do you think part of your loss is due to stocking up too much?

- Yes
- No
- Maybe

Feedback to responses:

Yes

- *True*
    - *That is correct. It is important to pay attention to how much stock you need to survive through Month {{NUM_ROUNDS}}. Your stock should never be greater than {{NUM_ROUNDS}} + 1.*
- *False*
    - *It appears that you did not have any opportunity cost due to stocking too much.*

No

- True
  - It appears that you did not have any opportunity cost due to stocking too much.
- False
  - It appears that you did have opportunity cost due to stocking too much. It is important to pay attention to how much stock you need to survive through Month {{NUM_ROUNDS}}. Your stock should never be greater than {{NUM_ROUNDS}} + 1.

Maybe

- *True*
  - *It appears that you did have opportunity cost due to stocking too much. It is important to pay attention to how much stock you need to survive through Month {{NUM_ROUNDS}}. Your stock should never be greater than {{NUM_ROUNDS}} + 1.*
- *False*
  - *It appears that you did not have any opportunity cost due to stocking too much.*

Are you convinced that [you incurred no losses | you have incurred losses] due to stocking up too much?

- Yes
- No

Appendix B.2. Descriptive statistics

Appendix B Table 1 - Descriptive statistics of subjects

	Mean	Standard deviation	Minimum	50%	Maximum
Age	32.43	8.38	18.00	30.50	59.00
Gender (% female)	51	—	—	—	—
Education level	2.58	—	0.00	3.00	4.00
Employment status	1.07	—	0.00	1.00	4.00
Monthly income	2.29	—	0.00	2.00	5.00
Ability to save (% able)	81	—	0.00	1.00	1.00
Monthly savings	2.85	—	0.00	3.00	7.00
Acquired debt in last 12 month (%)	14	—	0.00	0.00	1.00
Amount of debt held	0.69	—	0.00	0.00	7.00
Holds stocks (%)	32	—	0.00	0.00	1.00
Holds mutual funds (%)	6	—	0.00	0.00	1.00
Holds bonds (%)	8	—	0.00	0.00	1.00
Holds savings accounts (%)	87	—	0.00	1.00	1.00
Holds life insurance (%)	40	—	0.00	0.00	1.00
Holds retirement accounts (%)	16	—	0.00	0.00	1.00
Holds cryptocurrencies (%)	21	—	0.00	0.00	1.00

Appendix B.3. Results of inflation measures

Appendix B Table 2 - Correlation matrix: Inflation measures

	Qualitative perception, low inflation	Qualitative perception, high inflation	Qualitative expectation, low inflation	Qualitative expectation, high inflation	Avg Qualitative perception Accuracy	Avg Qualitative expectation Accuracy	Average Uncertain Expectation	Perception bias, high inflation	Perception bias, low inflation	Perception sensitivity	Expectation bias, high inflation	Expectation bias, low inflation	Expectation sensitivity	Purchase adaptation	Purchase adaptation (%)	Final savings
Qualitative perception, low inflation	—															
Qualitative perception, high inflation	0.09	—														
Qualitative expectation, low inflation	0.3***	0.36***	—													
Qualitative expectation, high inflation	0.21***	0.43***	0.5***	—												
Avg Qualitative perception Accuracy	-0.47***	0.74***	0.15*	0.19**	—											
Avg Qualitative expectation Accuracy	0.12	0.31***	0.42***	0.7***	0.13	—										
Average Uncertain Expectation	0.11	0.4***	0.35***	0.17**	0.27***	0.16**	—									
Perception bias, high inflation	-0.04	0.46***	0.27***	0.17**	0.37***	0.12	0.49***	—								
Perception bias, low inflation	0.56***	-0.06	0.25***	0.05	-0.39***	0.02	0.29***	0.32***	—							
Perception sensitivity	-0.44***	0.64***	0.12	0.25***	0.71***	0.19**	0.22***	0.44***	-0.34***	—						

	Qualitative perception, low inflation	Qualitative perception, high inflation	Qualitative expectation, low inflation	Qualitative expectation, high inflation	Avg Qualitative perception Accuracy	Avg Qualitative expectation Accuracy	Average Uncertain Expectation	Perception bias, high inflation	Perception bias, low inflation	Perception sensitivity	Expectation bias, high inflation	Expectation bias, low inflation	Expectation sensitivity	Purchase adaptation	Purchase adaptation (%)	Final savings
Expectation bias, high inflation	0.05	0.35***	0.37***	0.46***	0.24***	0.29***	0.46***	0.78***	0.28***	0.31***	—					
Expectation bias, low inflation	0.34***	0.02	0.44***	0.12	-0.19**	0.11	0.44***	0.42***	0.82***	-0.14*	0.43***	—				
Expectation sensitivity	-0.07	0.38***	0.04	0.24***	0.34***	0.24***	0.17**	0.18**	-0.18**	0.36***	0.2**	-0.22***	—			
Purchase adaptation	-0.02	0.13	0.1	0.14*	0.11	0.15*	0.07	0.18**	0.01	0.1	0.26***	0.04	0.16**	—		
Purchase adaptation (%)	-0.05	0.12	0.07	0.12	0.13	0.13	0.06	0.17**	-0.04	0.1	0.25***	-0.01	0.18**	0.97***	—	
Final savings	-0.22***	0.27***	0.12	0.19**	0.36***	0.26***	-0.02	0.15*	-0.24***	0.29***	0.21***	-0.15*	0.26***	0.47***	0.48***	—

Appendix B Table 3 - Quantitative estimate statistics

		High inflation	**Low inflation**
Quantitative perception estimates	Mean	22.22	5.42
	Std	23.85	11.66
Quantitative expectation estimates	Mean	15.81	6.21
	Std	21.84	12.60

Appendix B.4. Supplemental results from previous experiment

Appendix B Table 4 - OLS regressions of performance measures for 4x30 inflation sequence, pre-treatment

Variables	(1) Final savings (%)	(2) Over-stock (%)	(3) Wasteful-stock (%)
Intercept	0.3342***	0.4038***	0.1952***
	(0.0489)	(0.0562)	(0.0389)
Expectation sensitivity	-0.0307	-0.1170	0.1268**
	(0.0648)	(0.0745)	(0.0515)
Expectation bias	-0.0001	0.0007	0.0006
	(0.0012)	(0.0014)	(0.0010)
Perception sensitivity	0.2481***	-0.1107	-0.2104***
	(0.0711)	(0.0817)	(0.0565)
Perception bias	0.0003	0.0004	-0.0005
	(0.0008)	(0.0009)	(0.0006)
R-squared	0.1149	0.0547	0.1612
R-squared Adj.	0.0788	0.0161	0.1270

Standard errors in parentheses.

* p<.1, ** p<.05, *** p<.01

Appendix B Table 5 - Correlation matrix: Inflation measures (4x30 sequence)

	Perception bias, high inflation	Perception bias, low inflation	Perception sensitivity	Expectation bias, high inflation	Expectation bias, low inflation	Expectation sensitivity	Purchase adaptation	Purchase adaptation (%)	Final savings
Perception bias, high inflation	—								
Perception bias, low inflation	0.61***	—							
Perception sensitivity	0.29***	-0.36***	—						
Expectation bias, high inflation	0.79***	0.56***	0.16***	—					
Expectation bias, low inflation	0.62***	0.71***	-0.09***	0.79***	—				
Expectation sensitivity	0.07**	-0.13***	0.11***	0.08***	-0.27***	—			
Purchase adaptation	0.27***	0.14***	0.18***	0.19***	0.07**	0.16***	—		
Purchase adaptation (%)	0.31***	0.21***	0.15***	0.19***	0.08***	0.14***	0.91***	—	
Final savings	0.01	-0.09***	0.19***	-0.07**	-0.07**	0.05	0.15***	0.18***	—

Appendix B.5. Results of individual characteristic measures

Appendix B Table 6 - Knowledge measures

	Distribution of subject
Financially literate	51%
Numerate	30%
Compound interest-capable	47%

Appendix B Table 7 - Economic preference task results

	Mean	Standard deviation	Minimum	50%	Maximum
Loss aversion, coin tosses	2.40	1.43	0.00	2.00	6.00
Loss aversion, switches	1.11	0.68	0.00	1.00	4.00
Risk aversion, safe choices	5.68	1.88	0.00	6.00	10.00
Risk aversion, switches	1.42	1.24	0.00	1.00	7.00
Time preferences, smaller-sooner choices	7.64	4.50	1.00	7.00	20.00
Time preferences, switches	2.14	1.23	0.00	2.00	12.00
WCST, number correct	17.08	6.32	1.00	18.00	25.00
WCST, perseverative errors	4.34	4.86	0.00	3.00	25.00
WCST, set-loss errors	1.82	2.06	0.00	1.00	10.00

Appendix B Table 8 -Correlations: Knowledge measures and in-task performance measures

Measure	Performance measure	Correlation
Financially literate	Total savings	0.26
Financially literate	Wasteful-stocking	-0.28
Numerate	Total savings	0.27
Numerate	Purchase adaptation	0.24
Compound interest-capable	Total savings	0.33
Compound interest-capable	Wasteful-stocking	-0.27
Compound interest-capable	Purchase adaptation	0.24

Appendix B Table 9 - Correlations: Economic preference measures and in-task performance measures

Measure	Performance measure	Correlation
Risk aversion, switches	Total savings	-0.28
Risk aversion, switches	Wasteful-stocking	0.32
Time preferences, switches	Total savings	-0.33
Time preferences, switches	Wasteful-stocking	0.37
WCST, number correct	Total savings	0.28
WCST, number correct	Wasteful-stocking	-0.28
WCST, perseverative errors	Total savings	-0.28
WCST, perseverative errors	Wasteful-stocking	0.30

Appendix B Table 10 - Correlations: Knowledge measures and in-task inflation measures

Measure	Inflation measure	Correlation
Numerate	Perception sensitivity	0.24

Appendix B Table 11 - Correlations: Time preferences and in-task inflation measures

Measure	Inflation measure	Correlation
Time preferences, switches	Perception sensitivity	-0.23

Appendix B Table 12 - Correlations: Wisconsin card sorting task and in-task inflation measures

Measure	Inflation measure	Correlation
WCST, number correct	Perception sensitivity	0.24
WCST, perseverative errors	Perception sensitivity	-0.24

Appendix B Table 13 - Correlations: Knowledge measures and in-task qualitative inflation measures

Measure	Inflation measure	Correlation
Numerate	Avg qualitative perception accuracy	0.26

Appendix B Table 14 - Correlations: Time preferences and in-task qualitative inflation measures

Measure	Inflation measure	Correlation
Time preferences, smaller-sooner choices	Avg qualitative perception accuracy	-0.28
Time preferences, switches	Avg qualitative expectation accuracy	-0.22

Appendix B Table 15 - Correlations: Wisconsin card sorting task and in-task qualitative inflation measures

Measure	Inflation measure	Correlation
WCST, number correct	Avg qualitative expectation accuracy	0.30
WCST, perseverative errors	Avg qualitative expectation accuracy	-0.29

Appendix B.6. Ordinary least squares regression of individual characteristics and treatment

Appendix B Table 16 - OLS regressions: Change in performance on treatment and individual characteristics

Variables	(1) Final savings (%)	(2) Over-stocking (%)	(3) Wasteful-stocking (%)
Intercept	-0.2145	0.1981	-0.1085
	(0.3358)	(0.2771)	(0.0769)
Treatment, Control × Financially literate	-0.0755	-0.0006	-0.0060
	(0.1137)	(0.0938)	(0.0260)
Treatment, Intervention 1 × Financially literate	-0.1660	0.1020	-0.0083
	(0.1211)	(0.0999)	(0.0277)
Treatment, Intervention 2 × Financially literate	-0.0525	-0.0021	0.0034
	(0.1037)	(0.0855)	(0.0237)
Treatment, Control × Numerate	0.0057	-0.1123	0.0253
	(0.1623)	(0.1339)	(0.0372)
Treatment, Intervention 1 × Numerate	-0.0576	0.0616	-0.0115
	(0.1347)	(0.1111)	(0.0308)
Treatment, Intervention 2 × Numerate	-0.0095	-0.0067	0.0295
	(0.1017)	(0.0839)	(0.0233)
Treatment, Control × Compound	0.1434	-0.0755	0.0078
	(0.1205)	(0.0994)	(0.0276)
Treatment, Intervention 1 × Compound	0.2122	-0.1160	0.0202
	(0.1363)	(0.1124)	(0.0312)
Treatment, Intervention 2 × Compound	-0.0120	0.0527	0.0090
	(0.1020)	(0.0842)	(0.0234)
Treatment, Control × WCST, number correct	-0.0012	0.0023	0.0023
	(0.0148)	(0.0122)	(0.0034)
Treatment, Intervention 1 × WCST, number correct	-0.0013	0.0007	0.0021
	(0.0123)	(0.0102)	(0.0028)
Treatment, Intervention 2 × WCST, number correct	0.0215	-0.0174	0.0041
	(0.0149)	(0.0123)	(0.0034)
Treatment, Control × WCST, set-loss errors	-0.0110	0.0147	-0.0032
	(0.0266)	(0.0219)	(0.0061)
Treatment, Intervention 1 × WCST, set-loss errors	-0.0711**	0.0372	0.0099
	(0.0313)	(0.0258)	(0.0072)
Treatment, Intervention 2 × WCST, set-loss errors	-0.0027	-0.0104	0.0027
	(0.0250)	(0.0207)	(0.0057)
Treatment, Control × WCST, perseverative errors	-0.0027	0.0056	-0.0016
	(0.0177)	(0.0146)	(0.0040)
Treatment, Intervention 1 × WCST, perseverative errors	-0.0044	0.0064	-0.0005
	(0.0176)	(0.0145)	(0.0040)
Treatment, Intervention 2 × WCST, perseverative errors	0.0243	-0.0254	0.0064
	(0.0206)	(0.0170)	(0.0047)
Treatment, Control × Risk aversion, safe choices	0.0217	-0.0218	0.0043
	(0.0291)	(0.0240)	(0.0067)
Treatment, Intervention 1 × Risk aversion, safe choices	0.0109	-0.0356	0.0196***
	(0.0274)	(0.0226)	(0.0063)

Treatment, Intervention 2 × Risk aversion, safe choices	-0.0120	0.0178	-0.0027
	(0.0278)	(0.0229)	(0.0064)
Treatment, Control × Risk aversion, switches	0.0949**	-0.0985**	0.0109
	(0.0479)	(0.0395)	(0.0110)
Treatment, Intervention 1 × Risk aversion, switches	-0.0625	0.0465	0.0068
	(0.0512)	(0.0422)	(0.0117)
Treatment, Intervention 2 × Risk aversion, switches	-0.0441	0.0444	-0.0057
	(0.0506)	(0.0417)	(0.0116)
Treatment, Control × Loss aversion, coin tosses	0.0009	-0.0013	0.0017
	(0.0350)	(0.0289)	(0.0080)
Treatment, Intervention 1 × Loss aversion, coin tosses	0.0213	-0.0119	0.0047
	(0.0358)	(0.0295)	(0.0082)
Treatment, Intervention 2 × Loss aversion, coin tosses	-0.0086	-0.0039	0.0041
	(0.0457)	(0.0377)	(0.0105)
Treatment, Control × Loss aversion, switches	0.0371	-0.0795	0.0426***
	(0.0643)	(0.0531)	(0.0147)
Treatment, Intervention 1 × Loss aversion, switches	0.0753	-0.0086	-0.0436**
	(0.0927)	(0.0765)	(0.0212)
Treatment, Intervention 2 × Loss aversion, switches	0.0359	0.0083	-0.0097
	(0.0938)	(0.0774)	(0.0215)
Treatment, Control × Time preferences, smaller-sooner choices	-0.0231*	0.0165	-0.0004
	(0.0135)	(0.0112)	(0.0031)
Treatment, Intervention 1 × Time preferences, smaller-sooner choices	0.0407***	-0.0197*	-0.0079**
	(0.0142)	(0.0118)	(0.0033)
Treatment, Intervention 2 × Time preferences, smaller-sooner choices	-0.0069	0.0035	0.0019
	(0.0105)	(0.0087)	(0.0024)
Treatment, Control × Time preferences, switches	-0.0352	0.0869	-0.0138
	(0.1511)	(0.1247)	(0.0346)
Treatment, Intervention 1 × Time preferences, switches	0.0077	-0.0027	-0.0005
	(0.0316)	(0.0261)	(0.0072)
Treatment, Intervention 2 × Time preferences, switches	0.0292	-0.0321	-0.0039
	(0.0538)	(0.0444)	(0.0123)
R-squared	0.3064	0.3109	0.3185
R-squared Adj.	0.0930	0.0989	0.1088

Standard errors in parentheses.

* p<.1, ** p<.05, *** p<.01

Appendix B.7. Mediation analysis results

Appendix B Table 17 - Mediation analysis of control

Path	Coefficient	STE	p value
Change in average qualitative perceptions ~ Control	-0.02	0.02	0.31
Change in average qualitative expectations ~ Control	0.02	0.02	0.45
Change in average expectation uncertainty ~ Control	0.03	0.03	0.39
Change in perception sensitivity ~ Control	0.03	0.04	0.44
Change in perception bias ~ Control	0.08	1.10	0.95
Change in expectation sensitivity ~ Control	-0.06	0.05	0.22
Change in expectation bias ~ Control	-0.06	1.12	0.96
Change in final savings ~ Change in average qualitative perceptions	0.07	0.12	0.56
Change in final savings ~ Change in average qualitative expectations	-0.02	0.12	0.86
Change in final savings ~ Change in average expectation uncertainty	-0.30	0.08	0.00
Change in final savings ~ Change in perception sensitivity	0.07	0.07	0.32
Change in final savings ~ Change in perception bias	-0.00	0.00	0.69
Change in final savings ~ Change in expectation sensitivity	0.07	0.05	0.14
Change in final savings ~ Change in expectation bias	0.00	0.00	0.38
Total	-0.28	0.04	0.00
Direct	-0.27	0.04	0.00
Indirect Change in average qualitative perceptions	-0.00	0.00	0.94
Indirect Change in average qualitative expectations	0.00	0.00	0.94
Indirect Change in average uncertainty	-0.01	0.01	0.43
Indirect Change in perception sensitivity	0.00	0.01	0.54
Indirect Change in perception bias	-0.00	0.00	0.98
Indirect Change in expectation sensitivity	-0.00	0.00	0.46
Indirect Change in expectation bias	-0.00	0.00	0.85

Appendix B Table 18 - Mediation analysis of Intervention 1

Path	Coefficient	STE	p value
Change in average qualitative perceptions ~ Intervention 1	0.03	0.02	0.12
Change in average qualitative expectations ~ Intervention 1	-0.01	0.02	0.71
Change in average expectation uncertainty ~ Intervention 1	-0.08	0.03	0.02
Change in perception sensitivity ~ Intervention 1	-0.04	0.04	0.27
Change in perception bias ~ Intervention 1	-1.65	1.12	0.14
Change in expectation sensitivity ~ Intervention 1	0.17	0.05	0.00
Change in expectation bias ~ Intervention 1	-0.84	1.14	0.46
Change in final savings ~ Change in average qualitative perceptions	0.07	0.12	0.56
Change in final savings ~ Change in average qualitative expectations	-0.02	0.12	0.86
Change in final savings ~ Change in average expectation uncertainty	-0.30	0.08	0.00
Change in final savings ~ Change in perception sensitivity	0.07	0.07	0.32
Change in final savings ~ Change in perception bias	-0.00	0.00	0.69
Change in final savings ~ Change in expectation sensitivity	0.07	0.05	0.14
Change in final savings ~ Change in expectation bias	0.00	0.00	0.38
Total	0.10	0.04	0.03
Direct	0.07	0.05	0.14
Indirect Change in average qualitative perceptions	0.00	0.01	0.82
Indirect Change in average qualitative expectations	0.00	0.00	0.98
Indirect Change in average uncertainty	0.02	0.01	0.02
Indirect Change in perception sensitivity	-0.00	0.00	0.46
Indirect Change in perception bias	0.00	0.01	0.77
Indirect Change in expectation sensitivity	0.01	0.01	0.22
Indirect Change in expectation bias	-0.00	0.01	0.64

Appendix B Table 19 - Mediation analysis of Intervention 2

Path	Coefficient	STE	p value
Change in average qualitative perceptions ~ Intervention 2	-0.01	0.02	0.62
Change in average qualitative expectations ~ Intervention 2	-0.01	0.02	0.71
Change in average expectation uncertainty ~ Intervention 2	0.05	0.03	0.16
Change in perception sensitivity ~ Intervention 2	0.01	0.04	0.77
Change in perception bias ~ Intervention 2	1.41	1.06	0.18
Change in expectation sensitivity ~ Intervention 2	-0.09	0.05	0.06
Change in expectation bias ~ Intervention 2	0.81	1.08	0.46
Change in final savings ~ Change in average qualitative perceptions	0.07	0.12	0.56
Change in final savings ~ Change in average qualitative expectations	-0.02	0.12	0.86
Change in final savings ~ Change in average expectation uncertainty	-0.30	0.08	0.00
Change in final savings ~ Change in perception sensitivity	0.07	0.07	0.32
Change in final savings ~ Change in perception bias	-0.00	0.00	0.69
Change in final savings ~ Change in expectation sensitivity	0.07	0.05	0.14
Change in final savings ~ Change in expectation bias	0.00	0.00	0.38
Total	0.17	0.04	0.00
Direct	0.20	0.04	0.00
Indirect Change in average qualitative perceptions	-0.00	0.00	0.84
Indirect Change in average qualitative expectations	0.00	0.00	0.94
Indirect Change in average uncertainty	-0.01	0.01	0.16
Indirect Change in perception sensitivity	0.00	0.00	0.91
Indirect Change in perception bias	-0.00	0.01	0.48
Indirect Change in expectation sensitivity	-0.01	0.01	0.12
Path	**Coefficient**	**STE**	**p value**

Appendix C.
Supplemental material: Chapter 3

Appendix C.1. Additional descriptive statistics

Appendix C Table 1 - Descriptive statistics, logarithmic difference

	CPI inflation	Expectations	Nondurables	Durables	Savings
Observations	558	558	558	558	558
Mean	0.29	-0.10	0.41	0.44	0.32
Standard deviation	0.37	13.81	1.14	2.88	15.87
Skewness	-0.13	1.13	-2.87	0.85	0.45
Kurtosis	2.95	34.63	47.23	17.50	17.94
Jarque-Bera	198.36***	27482.91***	51673.53***	7048.12***	7361.04***
Shapiro-Wilk	0.97***	0.75***	0.75***	0.82***	0.72***
Ljung-Box	1048.53***	74.34***	58.10**	62.76**	84.32***

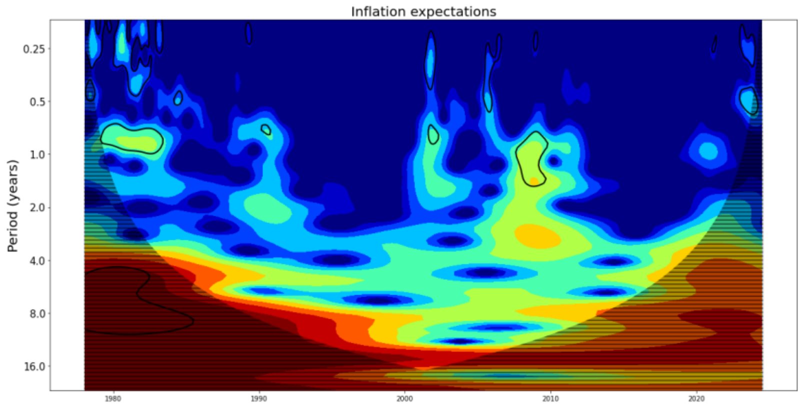
Appendix C Table 2 - Correlation matrix: Logarithmic differences of series in nominal and real terms

	CPI inflation	Expectations	Nondurables	Durables	Savings	Nondurables (Real)	Durables (Real)	Savings (Real)
CPI inflation	—							
Expectations	0.24***	—						
Nondurables	0.36***	0.16***	—					
Durables	0.0	-0.03	0.36***	—				
Savings	-0.1**	0.04	-0.27***	-0.31***	—			
Nondurables (Real)	0.03	0.09**	0.94***	0.38***	-0.25***	—		
Durables (Real)	-0.13***	-0.06	0.31***	0.99***	-0.3***	0.38***	—	
Savings (Real)	-0.12***	0.03	-0.28***	-0.31***	1.0***	-0.25***	-0.3***	—

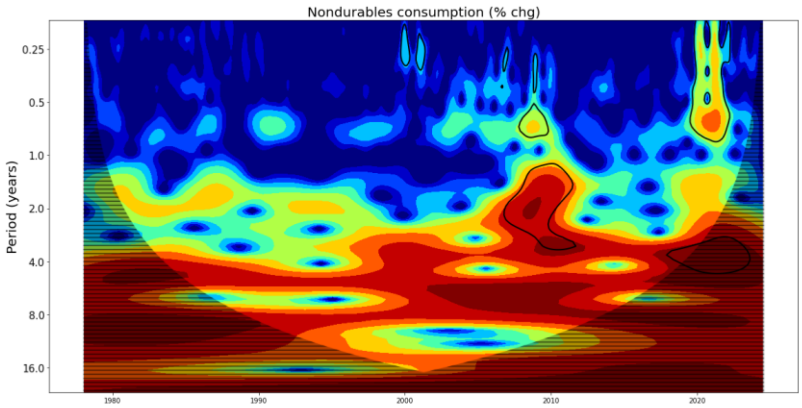
Appendix C Table 3 - Non-stationarity of CPI inflation over decades

Decade	Observations	Mean	Standard deviation	Minimum	25%	50%	75%	Maximum
1910	72.00	10.05	7.46	-0.98	2.02	12.56	17.42	20.74
1920	120.00	0.15	7.08	-15.79	-2.24	-0.58	2.38	23.67
1930	120.00	-1.95	5.04	-10.74	-6.45	-0.70	2.20	5.56
1940	120.00	5.66	5.47	-2.87	1.70	3.36	9.29	19.67
1950	120.00	2.07	2.44	-2.08	0.37	1.71	3.12	9.36
1960	120.00	2.33	1.48	0.67	1.31	1.64	3.14	6.20
1970	120.00	7.09	2.72	2.71	5.27	6.53	9.31	13.29
1980	120.00	5.56	3.53	1.10	3.64	4.25	6.46	14.76
1990	120.00	3.00	1.12	1.38	2.46	2.81	3.18	6.29
2000	120.00	2.57	1.44	-2.10	1.96	2.73	3.51	5.60
2010	120.00	1.77	0.86	-0.20	1.24	1.75	2.22	3.87
2020	55.00	4.35	2.56	0.12	2.55	3.67	6.43	9.06

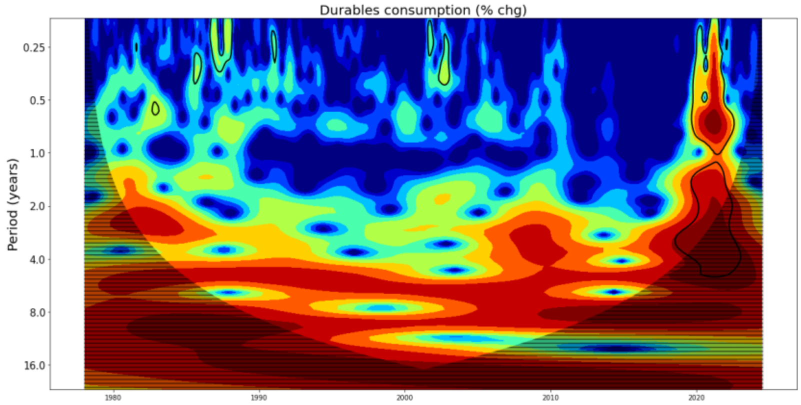
Appendix C.2. Continuous wavelet transforms of series in percentage terms



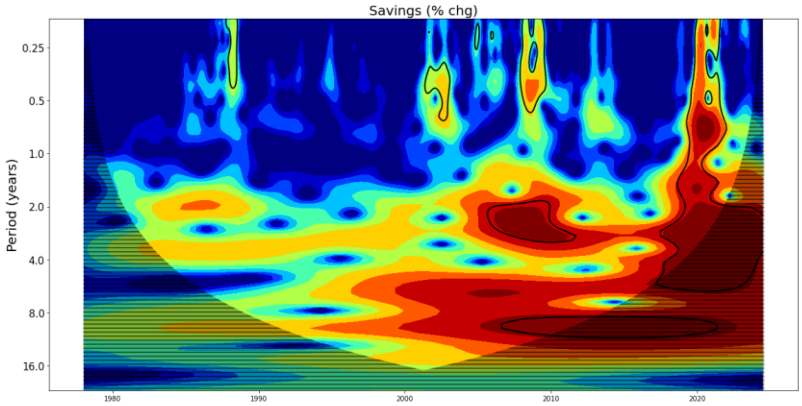
Appendix C Figure 1 - Power spectrum: Inflation expectations



Appendix C Figure 2 - Power spectrum: Nondurables consumption

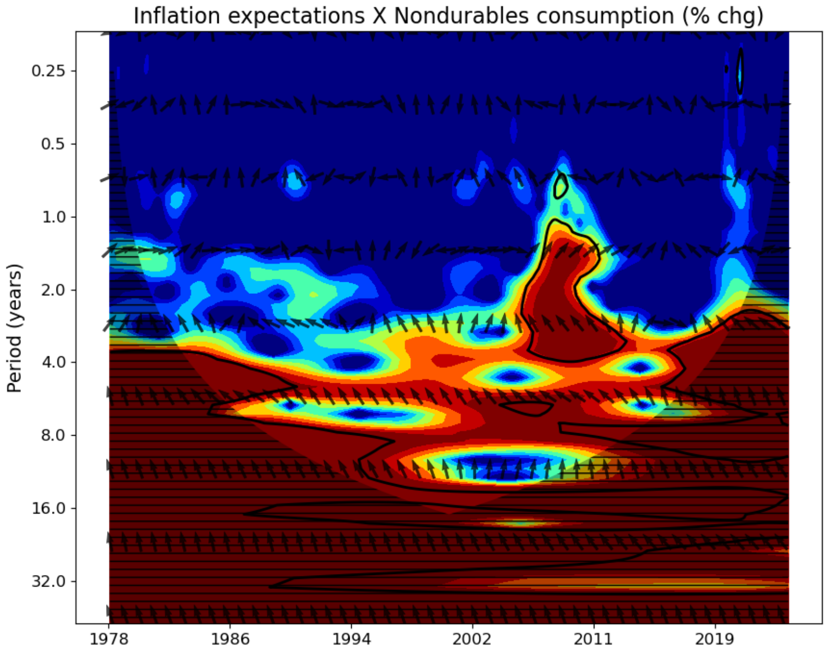


Appendix C Figure 3 - Power spectrum: Durables consumption

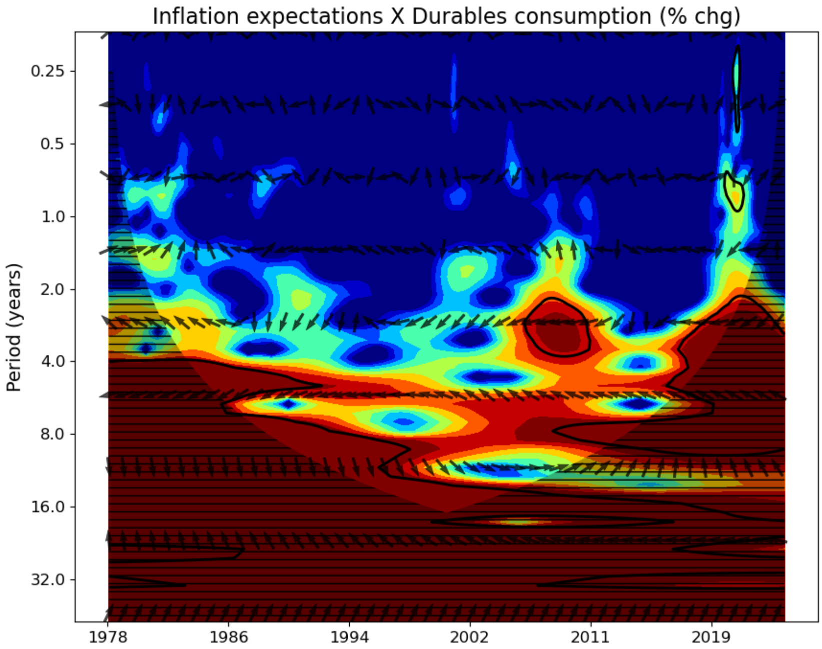


Appendix C Figure 4 - Power spectrum: Savings

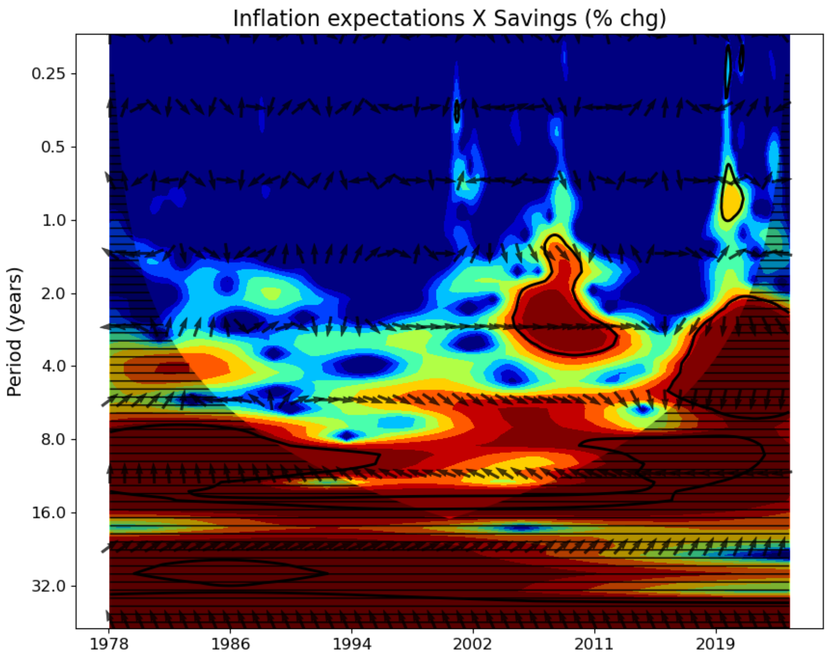
Appendix C.3. Cross-wavelet transforms of series in percentage terms



Appendix C Figure 5 - Cross-wavelet power spectrum: Inflation expectations and nondurables consumption



Appendix C Figure 6 - Cross-wavelet power spectrum: Inflation expectations and durable consumption



Appendix C Figure 7 - Cross-wavelet power spectrum: Inflation expectations and savings

Appendix C.4. Regressions in percentage terms

Appendix C Table 4 - Aggregate OLS regressions: Behavioral series on inflation expectations, percentage

	$y_{non,t}$	$y_{dur,t}$	$y_{sav,t}$
α	-0.2712	5.5920***	14.2253***
	(0.3039)	(0.7459)	(4.3745)
β	1.5009***	-0.0138	-0.9243
	(0.0772)	(0.1896)	(1.1118)
r^2	0.4044	0.0000	0.0012
r^2 Adj.	0.4033	-0.0018	-0.0006

Standard errors in parentheses.

* p<.1, ** p<.05, *** p<.01

Appendix C Table 5 - Time scale regression: Nondurables consumption on inflation expectations, percentage

	S_6	D_6	D_5	D_4	D_3	D_2	D_1
α_j	0.4030***	-0.0230	-0.0306	-0.0041	-0.0008	-0.0006	0.0000
	(0.1149)	(0.0496)	(0.0581)	(0.0505)	(0.0340)	(0.0272)	(0.0352)
β_j	1.3176***	3.7535***	2.5668***	2.7433***	1.2438***	1.0014***	0.1028
	(0.0299)	(0.1905)	(0.1295)	(0.2227)	(0.1419)	(0.1485)	(0.1744)
r^2	0.7769	0.4111	0.4140	0.2144	0.1214	0.0756	0.0006
r^2 Adj.	0.7765	0.4100	0.4130	0.2130	0.1198	0.0739	-0.0012

Standard errors in parentheses.

* p<.1, ** p<.05, *** p<.01

Appendix C Table 6 - Time scale regression: Durables consumption on inflation expectations, percentage

	S_6	D_6	D_5	D_4	D_3	D_2	D_1
α_j	4.9316***	-0.0453	-0.0536	-0.0063	-0.0053	-0.0022	0.0002
	(0.3828)	(0.0986)	(0.1286)	(0.1097)	(0.1106)	(0.0931)	(0.0822)
β_j	0.1867*	3.5314***	-1.5062***	-3.5007***	-0.5135	-1.0715**	-0.5427
	(0.0998)	(0.3791)	(0.2865)	(0.4836)	(0.4617)	(0.5077)	(0.4077)
r^2	0.0063	0.1350	0.0473	0.0861	0.0022	0.0079	0.0032
r^2 Adj.	0.0045	0.1334	0.0456	0.0845	0.0004	0.0062	0.0014

Standard errors in parentheses.

* p<.1, ** p<.05, *** p<.01

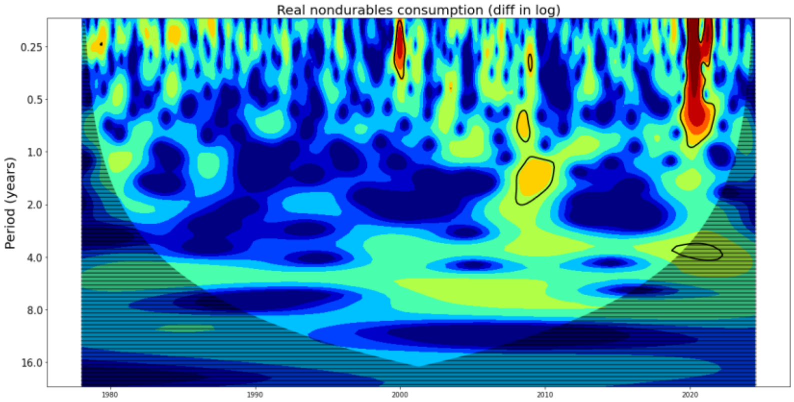
Appendix C Table 7 - Time scale regression: Savings on inflation expectations, percentage

	S_6	D_6	D_5	D_4	D_3	D_2	D_1
α_j	3.5985***	0.0506	-0.0257	-0.0005	0.0005	0.0004	-0.0000
	(0.1930)	(0.0311)	(0.0450)	(0.0328)	(0.0378)	(0.0259)	(0.0310)
β_j	0.9834***	-2.2379***	-0.9584***	-1.1126***	0.0391	-0.2479*	0.0372
	(0.0503)	(0.1194)	(0.1003)	(0.1444)	(0.1578)	(0.1413)	(0.1539)
r^2	0.4076	0.3871	0.1411	0.0965	0.0001	0.0055	0.0001
r^2 Adj.	0.4066	0.3860	0.1396	0.0948	-0.0017	0.0037	-0.0017

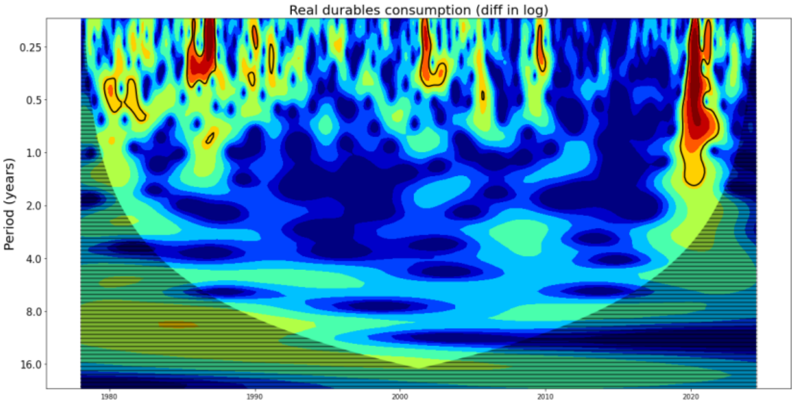
Standard errors in parentheses.

* p<.1, ** p<.05, *** p<.01

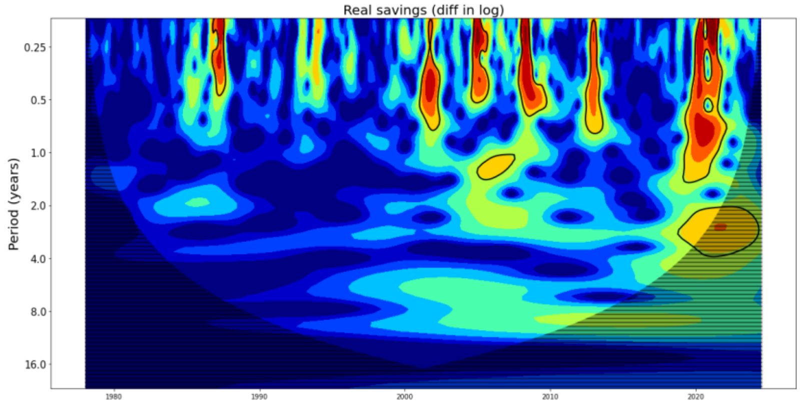
Appendix C.5. Continuous wavelet transforms of series in real terms



Appendix C Figure 8 - Real nondurables consumption

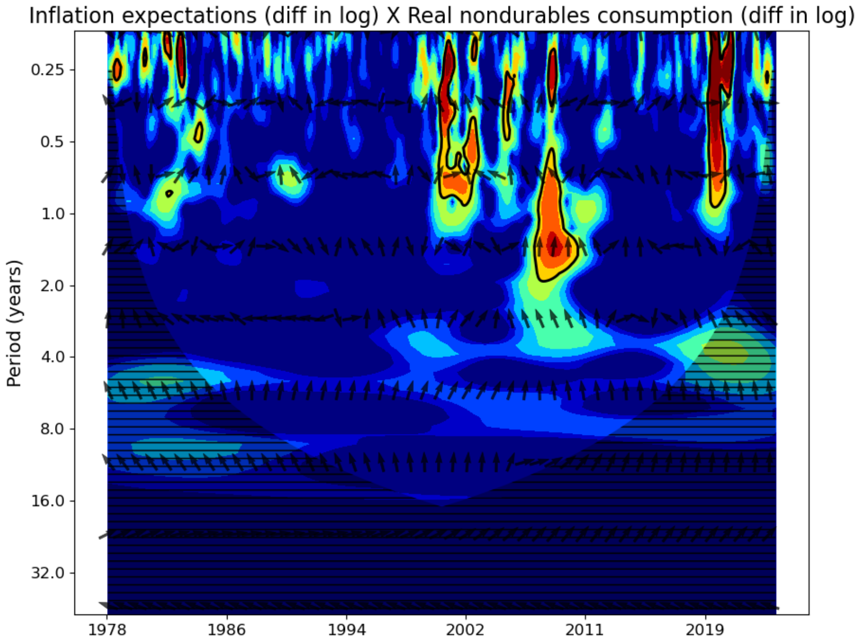


Appendix C Figure 9 - Power spectrum: Real durables consumption

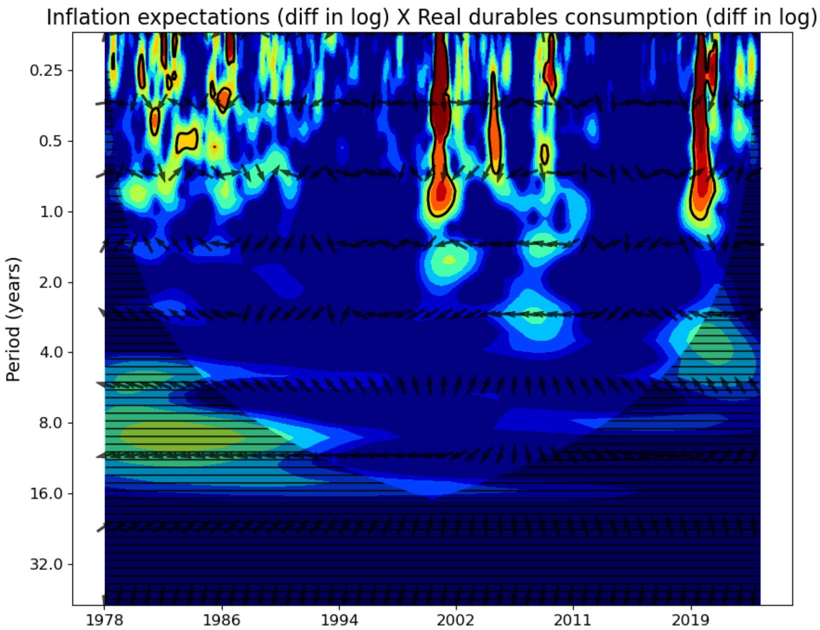


Appendix C Figure 10 - Power spectrum: Real savings

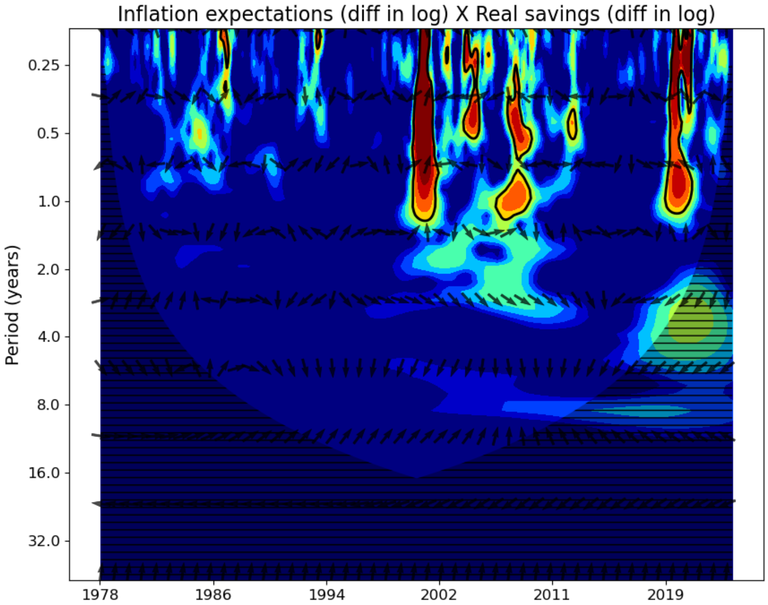
Appendix C.6. Cross-wavelet transforms of series in real terms



Appendix C Figure 11 - Cross-wavelet power spectrum: Inflation expectations and real nondurables consumption



Appendix C Figure 12 - Cross-wavelet power spectrum: Inflation expectations and real durables consumption



Appendix C Figure 13 - Cross-wavelet power spectrum: Inflation expectations and real savings

Appendix C.7. Regressions in real terms

Appendix C Table 8 - Aggregate OLS regressions: Real behavioral series on inflation expectations, logarithmic differences

	$y_{non,t}$	$y_{dur,t}$	$y_{sav,t}$
α	0.1175***	0.1443	0.0293
	(0.0437)	(0.1226)	(0.6741)
β	0.0069**	-0.0125	0.0372
	(0.0032)	(0.0089)	(0.0488)
r^2	0.0085	0.0036	0.0010
r^2 Adj.	0.0067	0.0018	-0.0008

Standard errors in parentheses.

* p<.1, ** p<.05, *** p<.01

Appendix C Table 9 - Time scale regression: Real nondurables consumption on inflation expectations, logarithmic differences

	S_6	D_6	D_5	D_4	D_3	D_2	D_1
α_j	0.1261***	-0.0004	-0.0004	-0.0035	-0.0007	-0.0001	0.0001
	(0.0026)	(0.0027)	(0.0028)	(0.0053)	(0.0109)	(0.0214)	(0.0349)
β_j	0.0234***	0.0611***	0.1106***	0.0373***	0.0129***	0.0234***	-0.0005
	(0.0066)	(0.0026)	(0.0029)	(0.0024)	(0.0025)	(0.0039)	(0.0030)
r^2	0.0219	0.4918	0.7259	0.2981	0.0455	0.0622	0.0000
r^2 Adj.	0.0201	0.4909	0.7254	0.2968	0.0438	0.0605	-0.0018

Standard errors in parentheses.

* p<.1, ** p<.05, *** p<.01

Appendix C Table 10 - Time scale regression: Real durables consumption on inflation expectations, logarithmic differences

	S_6	D_6	D_5	D_4	D_3	D_2	D_1
α_j	0.1375***	-0.0103	-0.0055	-0.0048	0.0012	0.0010	-0.0000
	(0.0111)	(0.0080)	(0.0122)	(0.0180)	(0.0264)	(0.0714)	(0.0918)
β_j	-0.2714***	0.0145*	0.0536***	0.0166**	-0.0380***	-0.0214*	-0.0094
	(0.0280)	(0.0078)	(0.0124)	(0.0082)	(0.0061)	(0.0129)	(0.0080)
r^2	0.1447	0.0062	0.0325	0.0073	0.0660	0.0049	0.0025
r^2 Adj.	0.1431	0.0045	0.0308	0.0055	0.0643	0.0032	0.0007

Standard errors in parentheses.

* p<.1, ** p<.05, *** p<.01

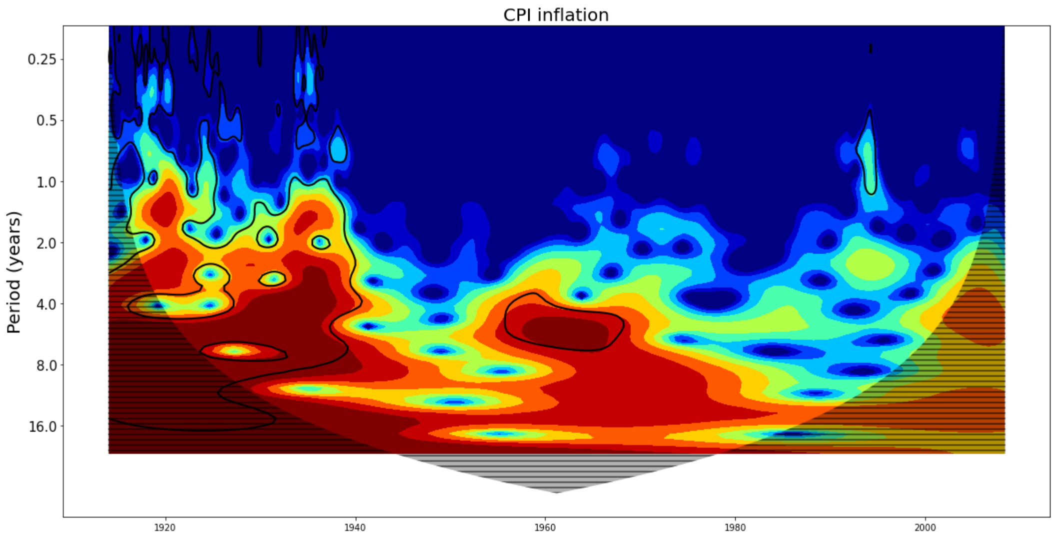
Appendix C Table 11 - Time scale regression: Real savings on inflation expectations, logarithmic differences

	S_6	D_6	D_5	D_4	D_3	D_2	D_1
α_j	-0.0552	0.0032	0.0392	0.0298	-0.0034	-0.0008	-0.0006
	(0.0339)	(0.0542)	(0.0874)	(0.1052)	(0.1818)	(0.3548)	(0.5183)
β_j	0.1675**	-0.3831***	-1.1824***	0.0417	0.0845**	0.1675***	0.0168
	(0.0852)	(0.0525)	(0.0889)	(0.0481)	(0.0418)	(0.0640)	(0.0449)
r^2	0.0069	0.0874	0.2415	0.0013	0.0073	0.0122	0.0003
r^2 Adj.	0.0051	0.0858	0.2401	-0.0004	0.0055	0.0104	-0.0015

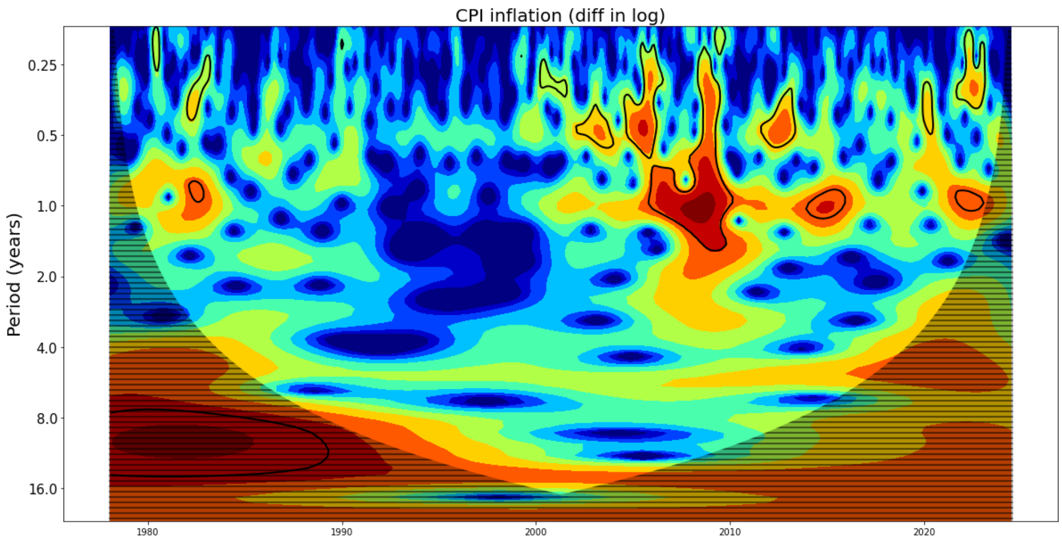
Standard errors in parentheses.

* p<.1, ** p<.05, *** p<.01

Appendix C.8. Wavelet analysis of CPI inflation



Appendix C Figure 14 -- Power spectrum: CPI inflation (all-time)



Appendix C Figure 15 - Power spectrum: CPI inflation

Inflation perception and behavior: Novel experimental and macroeconomic analyses

Abstract:

This thesis seeks to understand how economic agents—primarily household consumers—behave when faced with inflation. I examine how individuals perceive inflation and adapt their consumption and savings decisions accordingly. Given the inconsistent results in the existing literature on the inflation-consumer relationship, I develop and apply novel techniques to gain new perspectives both at the micro- and macroeconomic levels. I develop an experimental task to measure how subjects internalize and ultimately react to inflation. This experimental work provides a direct link between measures perceived and expected inflation and subsequent consumption and savings behavior. Using this finding, I can compare subjects' performance and adaptability to their individual characteristics to better understand the underlying traits that correlate with decision-making in inflation. In particular, numerical abilities, consistency of economic decision-making, and general adaptability are strong predictors of task performance. Further, through different financial education treatments, I identify effective means of educating consumers on appropriate decision-making in inflationary conditions—particularly by providing personalized feedback and easily actionable advice. Finally, through wavelet analysis, I demonstrate how the inconsistent expectations-consumption relationship found in the literature may in fact arise from an underlying cyclical nature. Moreover, I find supporting evidence of the positive relationship between expectations and nondurables consumption at the macro-level as identified at the individual level through my experimental methods.

Keywords:

Inflation, Experimental economics, Behavioral economics, Wavelet analysis, Financial education

Perception d'inflation et comportement des agents : Nouvelles analyses expérimentales et macroéconomiques

Résumé :

Cette thèse cherche à comprendre comment les agents économiques, surtout les ménages, se comportent face à l'inflation. Elle s'intéresse à la manière dont les individus perçoivent l'inflation et adaptent leurs décisions économiques à son évolution. Étant donné l'incohérence des résultats de la littérature sur la relation inflation-comportement des ménages, je développe et applique de nouvelles techniques afin d'offrir de nouvelles perspectives tant à l'échelle individuelle que macroéconomique. Je développe une tâche expérimentale pour mesurer comment les participants intériorisent et réagissent à l'inflation. Ces expériences relient directement leurs perceptions et anticipations à leurs comportements. Je compare les performances des participants dans la tâche à leurs caractéristiques individuelles pour identifier celles qui influencent le comportement ; notamment les capacités numériques, la cohérence des choix économiques, et l'adaptabilité sont des bons prédicteurs de la performance. En outre, à travers différents traitements d'éducation financière, j'identifie des moyens efficaces d'éduquer les ménages à leur prise de décision face à l'inflation, notamment en fournissant des informations personnalisées et des conseils facilement appliqués. Finalement, à travers l'analyse par ondelettes, je démontre que l'incohérence de la relation anticipations-consommation dans la littérature peut en effet être résultat d'une nature cyclique sous-jacente. De plus, je trouve des preuves à l'échelle macroéconomique d'une relation positive entre les anticipations et la consommation des bien non-durables similaire à celle de l'échelle individuelle trouvée par ces méthodes expérimentales.

Mots-clés :

Inflation, Économie expérimental, Économie comportementale, Analyse par ondelettes, Éducation financière

Nota : cette page, dernière de couverture, sera retournée avant reliure.