# Three Essays in Economics

Doctoral thesis for obtaining the
academic degree
Doctor of Economics (Dr. rer. pol.)

submitted by

**Annika Schürle**

at

Universität
Konstanz

Faculty of Politics, Law and Economics
Department of Economics

Konstanz, 2024

**Dissertation der Universität Kostanz**
Tag der mündlichen Prüfung: 23.Juli.2024

1. Referent: Prof. Dr. Volker Hahn
2. Referentin: Prof. Dr. Haomin Wang
3. Referent: Prof. Dr. Nawid Siassi

# Danksagung

Meine Jahre als Doktorandin habe ich als sehr intensiv und bereichernd empfunden. Diese Dissertation wäre ohne die Unterstützung meines fachlichen und privaten Umfelds kaum möglich gewesen.
An erster Stelle möchte ich meinen besonderen Dank meinem Doktorvater, Herrn Volker Hahn, ausdrücken. Sein konstruktives und hilfreiches Feedback und die unkomplizierten, oft spontanen Möglichkeiten des Austauschs waren mir stets eine große Unterstützung.
Insgesamt waren die Türen zu allen Mitgliedern der Makro Gruppe auf dem F2 Flur der Universität Konstanz immer offen. Ich möchte mich deshalb für die familiäre Stimmung und den Austausch bedanken. Mein Dank gilt insbesondere Stefan Niemann, Almuth Scholl, Haomin Wang, Nawid Siassi, Alessandro Di Nola, Oliko Vardishvili, Daniele Angelini, Océane Pietri, Alexander Matusche, Timm Prein, Anna Tkhir, Liang Tong, Florian Röser, Tim Hermann, Subashini Sundar, Tjantana Barro und Martin Wolf als externer Gast.
Darüber hinaus möchte ich meinen Mitdoktorandinnen und Mitdoktoranden Henrike Biehl, Mark Kapteina, Julie Schnaitmann, Simon Stehle, Tilmann Härtl, Michael Möller und Lennart Goldemann danken für die Wegbegleitung und die nötigen Kaffepausen.
Auch haben Raffael Kind, Till vom Heede und Marco Hilber als Studentische Hilfskräfte am Lehrstuhl für Monetary Economics in den Jahren meiner Promotion einen Teil zu dieser Dissertation beigetragen. Ich möchte auch ihnen für ihre zuverlässige Unterstützung danken.

Der Rückhalt durch meinen Freundeskreis, der mir in Konstanz und darüber hinaus geschenkt ist, war mir in stressigen Zeiten sehr wichtig. Danke, mein lieber Stammtisch, liebe Verena, liebe Rina, liebe Julia, liebe Xenia, für eure Loyalität und die wertvollen Momente der letzten Jahre! Ich vermisse die legendären Abende bei Jürgen und freue mich schon auf die nächsten vielen Jahre mit euch!
Danke liebe Caro, für dein offenes Ohr und deine positive Art. Danke für die schnellen und aufmerksamen Korrekturen, wenn es mal wieder geeilt hat. Ein großer Dank gilt auch meinen jüngeren Freunden Ida, Finjas, Yarie und Malou sowie ihren Eltern. Wie schön, dass es euch gibt!

Ohne die Unterstützung meiner Familie wäre ich nicht an dem Punkt, an dem ich heute stehe. Vielen Dank, Mama und Papa für für die Werte, die ihr mir mitgegeben habt und für eure bedingungslose Unterstützung in allem, was ich mache. Ich möchte auch meinen Geschwistern Moni, Markus, Tommi, Josi und Simone sowie ihren Familien danken: Danke für die vielen Taxifahrten zum Bahnhof Aalen und für euren Zusammenhalt.

Ohne eure finanzielle Hilfe wäre mir ein Studium nicht möglich gewesen. Dank gilt auch meiner Freundin Lola, die mir regelmäßig aufgezeigt hat, dass es im Leben wichtigeres als eine Doktorarbeit gibt.
An dieser Stelle möchte ich auch der ganzen Familie Ruf meinen Dank aussprechen für die lieben Karten, den Kaffee, die Kuchen und die Süßigkeiten, die meine Nerven in anstrengenden Zeiten genährt haben.

Meine größte Unterstützung warst und bleibst immer du, mein lieber Philipp. Du hast mir den nötigen Mut und Rückhalt gegeben, um diese Thesis zu beenden. Danke, dass du immer an meiner Seite bist.

# Table of Contents

# Introduction

This dissertation contains three research projects I worked on during my PhD at the Chair of Monetary Economics and the Graduate School of Decision Sciences at the University of Konstanz.
The resulting three chapters of my dissertation are related to the field of quantitative Macroeconomics and to the field of Household Finance.

The first chapter "*How Does Inflation Affect Different Age Groups?*" is joint work with Volker Hahn from the University of Konstanz. It is about the welfare effects of trend inflation on different generations of households. In particular, we focus on the impact of trend inflation on optimal wage setting of working households, where we impose nominal wage frictions and labor productivity growth over the working life cycle. We use a New Keynesian model with nominal price and wage frictions and individual productivity growth on the firm and on the household side. Both workers and firms have market power and they can choose their nominal wages and prices according to Calvo frictions.
Regarding the life cycle pattern of labor productivity, young individuals face strong and positive labor productivity growth. For middle-aged workers and workers close to retirement, individual labor productivity stagnates or even declines. This implies that young households want to adjust real wages upwards to a comparably strong degree, while older agents want to keep real wages rather constant.
Under positive trend inflation, real wages decline in period of sticky nominal wages. Young workers take into account the risk of future wage frictions by choosing high wage markups whenever they are able to adjust their wages. As high wage markups lead to low demand for young workers' labor and utlimately lead to consumption and welfare losses, households prefer deflation. Under negative trend inflation rates real wages increase even in periods where nominal wages are sticky.
Older households tend to be wealthy and tend to be more concerned about general equilibrium interest rates than younger individuals. Our model yields a general equilibrium inflation rate, which increases in trend inflation. Thus older workers and retirees prefer positive inflation rates.
For our considered welfare criteria, we find the optimal inflation rate generally to be negative unless nominal wages are fully flexible.
We conduct a politico-economic experiment where we assume that all individuals in the model economy can vote for a change in trend inflation by 1 percentage point. Taking into account the transitional dynamics after the inflation variation, we find that for an annual inflation rate of 2% no majority would vote for an increase or a decrease in trend inflation. Thus this inflation rate yields an equilibrium.

According to a traditional argument, positive inflation "*greases the wheels of the labor market*"[1] if nominal wages are sticky. Our model outcomes suggest that positive trend inflation can lead to high precautionary wage markup choices of young generations, which may have persistent negative labor market and wealth implications over the entire life cycle.

The second chapter "*House Price Inflation, Low Interest Rates and Housing Choice*" is co-authored with Alexander Braun and Julia Braun, both members of the University of St.Gallen. We investigate the relationship between strong increases in home values, very low interest rates and increasing inter-generational inequality regarding home ownership and wealth, starting from the 2000s.
In our empirical analysis using data from the Panel Study of Income Dynamics (PSID) we show that generations younger than the Baby boomers face significantly lower probabilities to participate at the housing market than the Baby boomer generation. These generations include generation X and the Millennials. Furthermore, observed households living in U.S. states with very strong house price inflation face a lower chance of being or becoming home owners than households living in states with more moderate house price inflation rates. Young cohorts living in states with strong increases in home values face particularly low probabilities to own a home.
In a partial equilibrium life cycle model with housing and mortgage choice, we investigate the effect of an environment of persistently low interest rates on housing decisions in the context of increasing house prices.
Under moderate house price inflation low interest rates are beneficial for prospect home owners, as lower mortgage rates make debt holdings more attractive. However, under strong house price inflation the dominance of the *down payment channel* leads to the opposite result: Both the increase in house values and the decline in returns to savings lead to an extended savings period for the down payment that has to be made in order to purchase a home. This implies a deferral in home purchases and declining home ownership rates among young working generations.
Our results show that the environment of strong house price inflation and very low interest rates has contributed to increased inter-generational wealth inequality. Home owners typically belonging to middle-aged and elderly generations, experienced appreciations of their home values. In contrast, younger generations with lower home ownership rates, could not benefit that much from the gains at the housing market and stored their wealth to a larger extent in assets bearing low returns.

In the third chapter "*Firm Market Power and Non-homothetic Preferences: Implications for Relative Prices*" I show that non-homothetic preferences can generate endogenous changes in relative prices during as a transitory shock accompanied by an income effect occurs.
Using CPI data I show that expenditure shares for typical necessity and luxury goods vary across the income distribution. I establish the stylized fact that prices of necessity goods follow aggregate inflation more strongly and even overshoot overall inflation

[1] see Tobin (1972)

than price of luxuries. This implies that relative prices of necessity goods vary more strongly than relative prices of luxuries. Firms producing necessities might take into account that the demand elasticity for their goods are comparably low and set their prices accordingly.

In order to account for non-homothetic preferences and endogenous markup choices in my theoretical framework, I add subsistence levels for individual consumption goods to a Dixit-Stiglitz aggregator function. Firms produce individual output goods under monopolistic competition and choose their relative prices taking into account the price elasticity of demand for their goods.

If a negative shock to aggregate productivity hits the economy, households experience a negative income effect. Demand for individual consumption goods declines towards the subsistence levels of the goods. As individual consumption approaches the subsistence level, demand for individual goods becomes less elastic. Less elastic demand functions translate into higher markup choices. This effect is especially pronounced for firms producing goods with high levels of subsistence. Thus, these firms increase their relative prices strongly.

The negative TFP shock becomes temporarily inflationary, if the model is extended by price frictions. Under this assumption prices of consumption goods with high degrees of necessity, thus high subsistence levels, increase comparably strongly, which generates inflation in the aggregate nominal price level. As relative prices for these goods should increase, their nominal prices increase by a stronger degree than aggregate inflation. Thus the inflation rate for goods with higher subsistence levels is above average inflation.

The model can give an explanation why low income households typically experience higher inflation in their consumption baskets than others in periods of high unexpected inflation. If prices for necessities increase particularily strongly due to their low substitutability, inflation has heterogeneous welfare effects across the income distribution.

# Einleitung

Diese Dissertation besteht aus drei Forschungsprojekten, an denen ich während meiner Zeit als Doktorandin am Lehrstuhl für Monetary Economics und an der Graduate School of Decision Sciences an der Universität Konstanz gearbeitet habe.
Die daraus resultierenden drei Kapitel meiner Dissertation gehören dem Gebiet der quantitativen Makroökonomik und der Household Finance Literatur an.

Das erste Kapitel "*How Does Inflation Affect Different Age Groups?*" is in Zusammenarbeit mit Volker Hahn von der Universität Konstanz entstanden. Wir beschäftigen uns darin mit den Wohlfahrtseffekten von Trendinflation auf unterschiedliche Generationen. Insbesondere betrachten wir die Implikationen von langfristiger Inflation auf die optimale Lohnsetzung arbeitender Haushalte. Dabei nehmen wir an, dass Nominallöhne Friktionen unterliegen und dass die Arbeitsproduktivität sich über den Lebenszyklus von Arbeitern verändert.
Wir betrachten ein neukeynesianisches Modell mit nominalen Preis- und Lohnrigiditäten sowie individuellem Produktivitätswachstum einzelner Firmen und Arbeiter. Wir nehmen an, dass sowohl Arbeiter, als auch Firmen einen gewissen Grad an Marktmacht besitzen und ihre nominalen Löhne und Preise unter Calvo Friktionen anpassen können.
Junge Arbeiter weisen typischerweise einen starken Anstieg in ihrer Arbeitsproduktivität auf. Für Arbeiter mittleren Alters und nahe dem Renteneintritt stagniert oder sinkt die Arbeitsproduktivität. Im Hinblick auf optimale Lohnanpassung bedeutet dies, dass junge Arbeiter ihre Reallöhne vergleichsweise stark erhöhen möchten, wohingegen mittelalte und ältere Arbeiter ihre Löhne eher konstant belassen wollen.
Betrachtet man nun den Fall von positiver Trendinflation, bedeutet dies, dass Reallöhne unter rigiden Nominallöhnen fallen. Entsprechend wählen junge Arbeiter hohe Markups in den Perioden, in denen Sie ihre Nominallöhne wählen können. Da hohe Markups eine geringe Arbeitsnachfrage und damit Konsum- und Wohlfahrtsverluste bedeuten, präferieren junge Arbeiter Deflation. Unter negativer Trendinflation steigen Reallöhne, selbst wenn Nominallöhne rigide sind.
Je älter die Arbeiter werden, desto vermögender sind sie. Deshalb spielt für sie der allgemeine Gleichgewichtszins auf die risikolosen Assets in der Volkswirtschaft eine wichtigere Rolle. Da der Realzins in unserem Modellergebnis steigend in der Inflationsrate verläuft, ziehen ältere Arbeiter und Rentner positive Inflationsraten vor.
Wir betrachten zwei Wohlfahrtskriterien und finden nutzenmaximierende Trendinflationsraten im negativen Bereich. Positive Inflation ist nur für den Spezialfall unseres Modells optimal, wenn von Lohnrigiditäten abstrahiert wird.
Für eine politik-ökonomische Analyse nehmen wir an, dass alle Individuen der Mo-

dellökonomie darüber abstimmen, ob die langfristige Inflationsrate um einen Prozentpunkt geändert werden soll. Wir berücksichtigten dabei die Übergangsdynamiken zum Steady State der neuen Inflationsrate. Die Abstimmungsergebnissen führen zu dem Resultat, dass für eine jährliche Trendinflationsrate von 2% keine Mehrheit für eine Erhöhung oder Senkung der Inflationsrate stimmt und damit ein Gleichgewicht erzielt ist.
Als klassisches Argument für positive Inflationsraten wird oft aufgeführt, dass "*Inflation die Räder des Arbeitsmarktes schmiert*"[2], sofern Nominallöhne rigide sind. Unsere Ergebnissen zeigen auf, dass positive Trendinflation auch zu vorsorglich hoch gewählten Löhnen junger Generationen führen kann, was negative Arbeitsmarkts- und Wohlfahrtimplikationen mit sich bringt.

Das zweite Kapitel "*House price inflation, low interest rates and housing choice*" ist ein gemeinschaftliches Projekt mit Alexander Braun und Julia Braun, beide der Universität St.Gallen angehörig. Wir untersuchen den Zusammenhang zwischen starkem Wachstum von Hauspreisen, sehr niedrigen Zinsen und ansteigender intergenerationeller Ungleichheit im Bezug auf Hauseigentum, was seit den 2000er Jahren beobachtet werden kann.
Für unsere empirische Analyse verwenden wir die Daten des Panel Study of Income Dynamice (PSID). Wir zeigen, dass für die Generationen X und die Millennials die Wahrscheinlichkeit, an dem Häusermarkt teilzuhaben, signifikant geringer ist, die Babyboomer Generation. Darüber hinaus haben beobachtete Haushalte, die in U.S. Staaten mit sehr starker Hauspreisinflation leben, eine geringere Chance, Hausbesitzer zu sein oder zu werden, als Haushalte, die in Bundesstaaten mit moderateren Hauspreisinflationsraten leben. Dabei ist für junge Kohorten, die in Staaten mit starkem Anstieg der Immobilienwerte leben, die Wahrscheinlichkeit geringer ein Haus zu besitzen, als für andere Altersgruppen.
Wir untersuchen den Effekt von persistent niedrigen Zinsen auf Hauskaufentscheidungen im Kontext steigender Hauspreise theoretisch. Dazu verwenden wir ein partielles Gleichgewichtsmodell, das Hauseigentum und Hauskredite als Entscheidungsvariablen beinhaltet. Unter moderater Hauspreisinflation sind niedrige Zinsen für zukünftige Hauseigentümer von Vorteil, da fallende Kreditzinsen Hauskredite attraktiver machen. Bei einem starken Anstieg der Hauspreise dominiert hingegen der *down payment channel*, was zu einem gegenteiligen Ergebnis führt. Sowohl der Anstieg der Immobilienwerte als auch der Rückgang der Sparrenditen führen zu einem längeren Sparzeitraum für die Anzahlung, die für den Kauf eines Hauses geleistet werden muss. Dieser Effekt führt zu späteren Hauskäufen im Lebenszyklus und zu sinkenden Hauseigentumsraten junger Generationen.
Unsere Ergebnisse zeigen, dass die Jahre starker Hauspreisinflation und niedriger Zinsen zu größerer Vermögensungleichheit zwischen den Generationen beigetragen haben. Hausbesitzer, die in der Regel der mittleren und älteren Generation angehören, erlebten eine Wertsteigerung ihrer Häuser. Im Gegensatz dazu konnten jüngere Generationen mit niedrigeren Wohneigentumsquoten weniger von den Gewinnen auf dem Wohnungs-

[2]siehe Tobin (1972)

markt profitieren und haben ihr Vermögen stattdessen in Anlagegütern mit niedrigen Renditen gehalten.

Im dritten Kapitel "*Firm Market Power and Non-homothetic Preferences: Implications for Relative Prices*" zeige ich, dass nicht-homothetische Präferenzen endogene Änderungen von Relativpreisen generieren können, wenn ein transitorischer aggregierter Schock auftritt, der mit einem Einkommenseffekt einhergeht.
Anhand von amerikanischen Verbraucherpreisindex Daten zeige ich dass die Ausgabenanteile von typischen Bedarfs- und Luxusgütern über die Einkommensverteilung variieren. Ich stelle eine stilisierte Gegebenheit dar, dass Preisanstiege von Bedarfsgütern stärker der aggregierten Inflationsrate folgen oder diese sogar übertreffen, als es für Preisentwicklungen von Luxusgütern der Fall ist. Unternehmen, die Güter des täglichen Bedarfs herstellen, könnten berücksichtigen, dass die Nachfrageelastizität für ihre Güter vergleichsweise gering ist, und ihre Preise entsprechend festlegen.
Ich beziehe nicht-homothetische Präferenzen sowie endogene Markups in mein Modell ein, indem ich Subsistenzniveaus für individuelle Konsumgüter zu einer Dixit-Stiglitz Aggregatorfunktion hinzufüge. Firmen produzieren einzelne Produktionsgüter unter monopolistischer Konkurrenz und wählen ihre relativen Preise unter Berücksichtigung der Preiselastizität der Nachfrage nach ihren Gütern.
Wenn ein negativer Schock auf die total Faktorproduktivität die Modellwirtschaft trifft, werden die Haushalte von einem negativen Einkommenseffekt betroffen. Die Nachfrage nach individuellen Konsumgütern verringert sich in Richtung der Subsistenzniveaus der jeweiligen Güter. Dadurch sinken die Preiselastizitäten der Nachfrage für die einzelnen Güter. Weniger elastische Nachfrage führen dazu, dass Firmen höhere Markups wählen. Dieser Effekt ist besonders für Firmen ausgeprägt, die Konsumgüter mit einem hohen Subsistenzniveau produzieren. Entsprechend erhöhen diese Firmen ihre relativen Preise stark.
Der negative TFP-Schock wird vorübergehend inflationär, wenn das Modell um Preisfriktionen erweitert wird. Unter dieser Annahme steigen Preise für Güter mit einem hohen Notwendigkeitsgrad, also einem hohen Subsistenzniveau, vergleichsweise stark an, was zu Inflation im aggregierten nominalen Preisniveau führt. Da die Relativpreise für diese Güter steigen sollten, wachsen ihre nominalen Preise stärker als die Gesamtinflation. Die Inflationsrate für Güter mit hohem Subsistenzniveau liegt also über der durchschnittlichen Inflationsrate.
Das Modell kann eine Erklärung dafür liefern, warum Haushalte mit niedrigen Einkommen in Zeiten hoher unerwarteter Inflation in der Regel höhere Inflationsraten in ihren Warenkörben verzeichnen als andere Haushalte. Wenn die Preise für notwendige Güter aufgrund ihrer geringen Substituierbarkeit besonders stark ansteigen, hat Inflation unterschiedliche Wohlfahrtseffekte über die Einkommensverteilung hinweg.

# Chapter 1

# How Does Inflation Affect Different Age Groups?

with Volker Hahn (University of Konstanz)

## Abstract

This paper proposes an overlapping-generations model with sticky wages and prices to examine which inflation rate is socially optimal. While flexible wages would result in positive optimal levels of inflation, we show that sticky wages, in combination with empirically plausible changes in productivity over workers' lives, make moderate deflation optimal. We also study intergenerational conflicts and show that young voters support a transition to lower inflation while older ones tend to support higher inflation rates.

I am grateful for many valuable comments and suggestions by Stefan Niemann, Henning Weber, Almuth Scholl, participants at the Konstanz-St. Gallen Workshop 2023, the Doctoral Workshop on Quantitative Dynamic Economics 2022 in Konstanz, as well as seminar participants at the University of Konstanz and Aix Marseille School of Economics.

# 1.1 Introduction

This paper analyzes how trend inflation affects different age groups. Moreover, we revisit the question of which trend inflation rates are optimal and ask how the answer to this question differs across age groups. For this purpose we study an overlapping-generations model with wage and price stickiness as well as three sources of productivity changes: (i) aggregate productivity growth, (ii) productivity growth for individual firms, and (iii) productivity changes of individual workers as they grow older. Under flexible prices and wages, these changes in productivities would lead to rather complex changes in relative prices over time. Sticky wages and goods prices distort relative prices compared to the benchmark with flexible price and wages. The magnitude of these distortions is affected by trend inflation in non-trivial ways.

When we abstract from wage rigidity, our model implies positive optimal rates of inflation of 2.75%, in line with a finding in the literature that, under sticky prices, positive trend inflation can be desirable as it automatically implies that older and more productive firms charge lower relative prices than young and less productive firms (Adam and Weber, 2019a). One of our main quantitative findings is that, when wages are sticky as well, age-dependent productivity together with aggregate growth can overturn this effect and can make deflation with an inflation rate of −3.75% optimal. Intuitively, for young and middle-aged workers, individual labor productivity increases over time. This entails that, under flexible prices and wages, real wages would increase as workers grow older. Negative rates of inflation allow to implement real wage decreases even in the absence of nominal wage adjustments. We thus extend an earlier result by Amano et al. (2009) that deflation can be optimal in the presence of sticky wages and aggregate productivity growth. First, we highlight the important role of workers' age-dependent productivity, which tends to make even lower rates of deflation desirable. Second, we show that the effects that tend to make deflation desirable dominate those that work through firm productivity growth and sticky prices and tend to make positive inflation desirable.

As younger workers have the steepest productivity increases over time, they tend to benefit more from low inflation rates than other workers.[1] To investigate intergen-

[1]Pallotti et al. (2023) provide empirical evidence that inflation affects different age groups differently. Bielecki et al. (2022) develop a new Keynesian model to examine the redistributive effects of monetary-policy shocks. While these authors consider temporary changes in inflation, we focus on the implications of different levels of trend inflation.

erational conflicts in more detail, we extend our model by incorporating a political dimension. Starting from an initial steady state of the economy with a given level of trend inflation, all individuals can vote in favor of or against a moderate permanent change in inflation, which would cause a transition to a new steady state. We find that 2% deflation would correspond to a politico-economic equilibrium, as a majority of voters would prefer not to raise or lower inflation in this case.[2] Hence the political process tends to result in an inflation rate that is higher than the socially optimal one. Thus our paper identifies a new source of inflation bias which is complementary to the traditional one that is due to time-inconsistent policies (Kydland and Prescott, 1977; Barro and Gordon, 1983).

Our model involves quite complex mechanisms regarding the consequences of inflation for aggregate variables and wealth accumulation over the life cycle. A key observation underlying these mechanisms is that positive inflation rates induce workers to choose high wage markups in order to avoid low real wages in the future, should they be unable to adjust their wage for some time. This effect is particularly pronounced for young workers, who would prefer real wages that rise over time, in line with their anticipated high gains in individual productivity. This has several implications.

First, high wage markups under high inflation tend to lead to a low level of employment. Second, aggregate productivity is high for high inflation rates due to a composition effect. Older workers with high levels of labor productivity work more compared to the relatively unproductive young. Third, high wage markups for young workers result in low labor incomes, which leads to less accumulation of wealth up to retirement and a lower stock of capital. Fourth, high inflation rates involve large adjustments of nominal wages by young workers whenever they are able to adjust their wages. Thus high inflation rates are associated with a high degree of income uncertainty. Fifth, there are two main channels via which high inflation affects the marginal product of capital. On the one hand, the comparably high levels of aggregate productivity resulting from high inflation tend to lead to a high marginal product of capital. On the other hand, the low levels of employment caused by high inflation contribute to a lower marginal product of capital. On balance, the first effect dominates. As a consequence, higher inflation rates are associated with higher real interest rates. The higher interest rates are attractive for middle-aged and old individuals for whom capital income is important.

[2] A related politico-economic equilibrium in an overlapping-generations model is studied in Gonzalez-Eiras and Niepelt (2008), who focus on social security.

When we analyze which inflation rate is chosen in the political process, we also take transition dynamics into account, which involve an additional channel that works through the stock market. A transition to higher inflation leads to lower output and profits and thereby to a sizable drop in stock prices. The drop in stock prices induces retirees and workers close to retirement, who are comparably wealthy, to oppose inflation rates higher than −2% despite the resulting increases in real interest rates that are desirable from their perspectives.

Our work contributes to the large literature on optimal inflation in the long run. (see Schmitt-Grohé and Uribe, 2010; Ascari and Sbordone, 2014; Diercks, 2017, for surveys). A classic argument stresses that higher inflation is associated with higher nominal interest rates and thus larger opportunity costs of holding money (see e.g. Fischer, 1981; Lucas, 1981). As a consequence, the Friedman rule, i.e. permanent deflation that eliminates the opportunity costs of holding money, is optimal. By contrast, zero inflation is typically welfare-maximizing in the standard new Keynesian model in the limiting case where real money balances are zero, as a constant price level alleviates the distortions in relative prices under staggered price setting.[3]

The consequences of a lower bound on nominal interest rates for the optimal rate of inflation are analyzed by Coibion et al. (2012) and Blanco (2021). Our analysis does not take the zero lower bound into account explicitly. However, a straightforward extension of our model to include nominal bonds would imply nominal interest rates above 3% and thus a non-binding effective lower bound. Nevertheless it is plausible that an effective lower bound together with the possibility of large aggregate shocks would call for higher inflation targets in our framework. At any rate, in light of the ongoing trend towards cashless societies and the introduction of central-bank digital currency, the effective lower bound may be less restrictive for monetary policy in the near future.

Second, our analysis is related to papers that study changes in trend inflation in models with productivity growth (Amano et al., 2009; Adam and Weber, 2019a, 2019b; Adam et al., 2022). Adam and Weber (2019a) propose a model where goods prices are sticky and individual firms become more productive over time. In this case, inflation of around 2% is optimal because it allows for relative prices to reflect the relative productivities of different generations of firms even if nominal prices are never adjusted. We extend

[3]The costs of price dispersion may be exaggerated by models with Calvo pricing that assume that firms cannot ration demand even if this was profitable to them (Hahn, 2022).

Adam and Weber's analysis by taking sticky wages as in Amano et al. (2009) and, in addition, productivity changes over workers' life cycles into account.

Third, while new Keynesian business cycle analysis often focuses on sticky goods prices, some authors argue that sticky wages may be even more important for understanding the dynamic effects of shocks (Erceg et al., 2000; Christiano et al., 2005; Amano et al., 2009; Broer et al., 2020; Auclert et al., 2023). By contrast, Basu and House (2016) highlight that the wage measure that is relevant for employment dynamics (e.g. the user cost of labor proposed by Kudlyak, 2014) is remarkably flexible. Gertler et al. (2020) criticize this view and argue that the measures of the user cost of labor employed by Kudlyak (2014) and Basu and House (2016) may be biased and that the true user cost of labor may be less cyclical than found by them. With the help of a micro data set on wages in Sweden, Björklund et al. (2019) show that nominal wage rigidity is important for understanding the real effects of monetary policy. Thus it may be plausible that sticky wages are relevant for the welfare effects of different levels of trend inflation as well.

Fourth, downward nominal wage rigidity (DNWR) is often argued to call for higher inflation rates (see Tobin, 1972, for example). Kim and Ruge-Murcia (2009) analyze a new Keynesian model and indeed find a rather small positive inflation rate of 0.35% to be optimal. More recently, Abbritti et al. (2021) identify an optimal inflation target exceeding 2% within a new Keynesian model incorporating DNWR and endogenous growth. To get an upper bound on the effects of DNWR in our framework, we construct a variant of our model in which nominal wage cuts are impossible. The combination of deflation and DNWR leads to real wages of individual workers that always increase over time. This has non-negligible consequences for older workers, whose individual labor productivity grows at low or even negative rates. We show that, in line with Riboni and Ruge-Murcia (2010) and Abbritti et al. (2021), DNWR leads to a higher optimal inflation rate. However, the optimal rate is $-1.0\%$ and thus still negative.

Our paper is organized as follows. The subsequent section lays out our model and specifies the parameter values for the numerical analysis. Section 1.3 highlights the effects of different trend inflation rates for markups, aggregate variables, and individual consumption. Moreover, we flesh out the intergenerational conflicts and identify the consequences of the level of steady-state inflation for welfare. In Section 1.4, we examine a variant of our model with downward nominal wage rigidity. Section 1.5 analyzes transition dynamics and provides our results about politico-economic equilibria, where individuals vote on permanent changes in trend inflation. We present our conclusions in Section 1.6.

# 1.2 Model

## 1.2.1 Set-up

We consider an overlapping-generations model with sticky prices and wages. The economy is populated by workers, retirees, intermediate-goods producers, perfectly competitive final-goods producers, and a monetary authority. There are $T$ generations of workers, where age is denoted by $\tau = 1, 2, ..., T$. After reaching age $T$, individuals are retired for $TR$ periods. They die after reaching age $\tau = T + TR$ and are replaced by new workers of age $\tau = 1$. The size of the population is normalized to one. We use $\lambda = \frac{T}{T+TR}$ to denote the share of workers in the population. Assuming a deterministic life span obviates the need to model accidental bequests. The interaction between age-specific productivity and sticky wages is plausible to be largely unaffected by this assumption.

Worker $i$'s utility in period $t$ is

$$u(C_{i,t}, H_{i,t}) = \ln(C_{i,t}) - \eta \frac{H_{i,t}^{1+\kappa}}{1+\kappa}, \tag{1.1}$$

where $\eta$ is a positive parameter and $\kappa$ the inverse Frisch elasticity of the labor supply. $H_{i,t}$ is the number of hours worked, $C_{i,t}$ final-goods consumption. Utility in future periods is discounted by factor $\beta \in (0, 1)$.

Workers $i$'s individual productivity is $G_{i,t}$, which is a function of age $\tau_{i,t}$:

$$G_{i,t} = g(\tau_{i,t}) \tag{1.2}$$

Effective labor $L_{i,t}$ and the number of hours worked by worker $i$, $H_{i,t}$, are related by $L_{i,t} = G_{i,t}H_{i,t}$. $W_{i,t}$ is the hourly nominal wage. In every period, workers are unable to adjust their nominal wage with probability $\omega \in [0, 1]$. Young workers of age 1 can choose their wages freely.

There are two different assets that workers can hold: physical capital $K_{i,t}$ with a rental rate $r_t$ and stocks $s_{i,t}$, which have an ex-dividend price $Q_t$. The stocks are claims on the profits $\Pi_t$ of intermediate-goods producers. The stock price is

$$Q_t = \sum_{s=1}^{\infty} \prod_{j=1}^{s} \frac{1}{1 + r_{t+j} - \delta} \Pi_{t+s}, \tag{1.3}$$

where $\delta$ is the depreciation rate. The aggregate supply of stocks is one.

In the steady state, both assets have identical returns as they are perfect substitutes. Later we will also examine unexpected shocks to the economy. In this case, the returns may be different ex post. Both assets are held in identical proportions by all individuals. This assumption does not affect our steady-state results but will be relevant for the effects of unanticipated shocks. Young workers of age $\tau = 1$ have zero assets when entering the economy.

Worker $i$'s budget constraint is

$$C_{i,t} + K_{i,t+1} + s_{i,t+1} Q_t = (1 + r_t - \delta) K_{i,t} + \frac{W_{i,t}}{P_t} H_{i,t} + s_{i,t} \Pi_t + s_{i,t} Q_t. \tag{1.4}$$

Retirees have the same utility functions and budget constraints as workers but cannot work, i.e. $H_{i,t} = 0$. We deliberately refrain from modeling the details of retirement benefits and assume that retirees use their own asset holdings to finance consumption. This is equivalent to a non-redistributive capital-based pension system. All individuals are borrowing constrained. More specifically, each individual $i$'s total asset holdings can never be negative.

Perfectly competitive final-goods producers combine intermediate goods produced by firms $f \in [0, 1]$ to a final good according to the technology

$$Y_t = \left[ \int_0^1 Y_{f,t}^{\frac{\varepsilon - 1}{\varepsilon}} df \right]^{\frac{\varepsilon}{\varepsilon - 1}}, \tag{1.5}$$

where $\varepsilon$ is the elasticity of substitution ($\varepsilon > 1$). Final goods can be used both for consumption and for investment. As is well-known, the final-goods producers' optimization problem entails that the demand for firm $f$'s intermediate good is

$$Y_{f,t} = \left( \frac{P_{f,t}}{P_t} \right)^{-\varepsilon} Y_t, \tag{1.6}$$

where $P_{f,t}$ is the nominal price chosen by firm $f$ and the price level $P_t$ satisfies

$$P_t = \left[ \int_0^1 P_{f,t}^{1-\varepsilon} df \right]^{\frac{1}{1-\varepsilon}}. \tag{1.7}$$

Each intermediate-goods producer $f$ rents capital and hires the different varieties of labor to produce intermediate-good variety $f$. The production function is

$$Y_{f,t} = A_t X_{f,t} K_{f,t}^{\alpha} L_{f,t}^{1-\alpha}, \tag{1.8}$$

where $A_t$ is aggregate productivity and $X_{f,t}$ firm-specific productivity. With slight abuse of notation, $K_{f,t}$ denotes the amount of capital rented by the firm and $L_{f,t}$ is the composite labor employed by firm $f$ (more details on this later). In period $t$, intermediate-goods producers use $D_{t,t+s} := \sum_{s=1}^{\infty} \prod_{j=1}^{s} \frac{1}{1+r_{t+j}-\delta}$ to discount profits in period $t+s$ $(s = 1, 2, ...)$.

Aggregate productivity $A_t$ evolves according to $A_t = aA_{t-1}$ with $a \geq 1$ and $A_0 = 1$. Following Adam and Weber (2019a), we assume that firm-specific productivity $X_{f,t}$ increases with firm age, i.e. $X_{f,t+1} = qX_{f,t}$ with $q > 1$. With constant probability $d \in (0, 1]$, firm $f$ exits the market at the end of each period and is replaced by a new firm. A new firm starts with $X_{f,t} = 1$.[4] In every period, a firm has to keep the previous period's nominal price with probability $\phi \in [0, 1]$. It is able to adjust it with probability $1 - \phi$. New firms can choose their prices freely.

Composite labor employed by firm $f$ is given by

$$L_{f,t} = \left[ \int_0^{\lambda} L_{f,i,t}^{\frac{\theta-1}{\theta}} di \right]^{\frac{\theta}{\theta-1}},$$

where $\theta > 0$ and $L_{f,i,t}$ is the amount of labor from worker $i$ that is hired by firm $f$.

Firm $f$'s cost-minimization problem entails that firm $f$'s demand for effective labor of type $i$ is

$$L_{f,i,t} = \left[ \frac{W_{i,t}}{G_{i,t} W_t} \right]^{-\theta} L_{f,t}, \tag{1.9}$$

[4] Adam and Weber (2019a) attribute the growth in $X_{f,t}$ to experience accumulation. In addition, they also consider a cohort trend according to which productivity is higher for firms that entered the market more recently compared to those that entered a long time ago. As the optimal inflation rate depends only on the ratio of the two corresponding growth rates, ignoring the cohort trend is without loss of generality and merely affects the interpretation of $q$.

$$W_t = \left[ \int_0^{\lambda} \left( \frac{W_{i,t}}{G_{i,t}} \right)^{1-\theta} di \right]^{\frac{1}{1-\theta}} . \tag{1.10}$$

As a consequence, the demand for worker $i$'s raw labor is

$$H_{i,t} = (G_{i,t})^{\theta-1} \left( \frac{W_{i,t}}{W_t} \right)^{-\theta} L_t, \tag{1.11}$$

where $L_t := \int_0^1 L_{f,t}\, df$. In addition, asset markets have to clear in every period $t$:

$$K_t = \int_0^1 K_{i,t}\, di = \int_0^1 K_{f,t}\, df, \tag{1.12}$$

$$\int_0^1 s_{i,t}\, di = 1. \tag{1.13}$$

Final-goods market clearing implies

$$C_t + K_{t+1} = Y_t + (1-\delta)K_t. \tag{1.14}$$

The monetary authority conducts monetary policy in a way such that inflation is fixed at $\pi$. For example, monetary policy could be implemented via an interest-rate rule.

The equilibrium concept is standard. In every period, workers choose consumption, asset holdings for the next period, and, in periods where they can adjust wages, nominal wages subject to their budget constraints and borrowing constraints to maximize the present value of current and future per-period utility. Their individual state variables are age, wealth, and the nominal wage inherited from the previous period (unless they are able to adjust the wage). The optimization problem of the retirees is analogous with the only difference that they cannot work and thus there is also no nominal wage for them. Final-goods producers select optimal bundles of intermediate goods, taking the prices of these intermediate goods as given. This leads to the demand for intermediate goods specified in (1.6). Intermediate-goods producers choose optimal amounts of capital and varieties of labor and, whenever possible, optimal prices of their goods in order to maximize the present value of their profits. The individual state variables are firm-specific productivity $X_{f,t}$ and, in periods where price adjustment is not possible, the previous period's price. The optimal choices of labor entail (1.11). Moreover, asset markets and goods markets have to clear. More details on the firms' and workers' optimization problems, which lead to the optimal price and wage choices, can be found in Appendix 1.A.

In order to analyze steady states, it is useful to recognize that real variables like aggregate output, consumption, and labor grow at rate $a^{\frac{1}{1-\alpha}}$ in the long run. Thus we introduce detrended variables by dividing by $\left(a^{\frac{1}{1-\alpha}}\right)^t$. Detrended variables are denoted by $\sim$. In a steady-state, detrended real variables are constant over time.

### 1.2.2 Aggregate output

In the following, we discuss how aggregate output is determined in equilibrium, which will be useful for the discussion of our results later. Combining (1.6) and (1.8), taking into account that $K_{f,t}/L_{f,t} = K_t/L_t$ holds for all firms $f$, and integrating yields

$$Y_t = A_t A_t^G K_t^\alpha L_t^{1-\alpha}, \tag{1.15}$$

where $A_t^G$ is the inverse of the measure of price dispersion often used in new Keynesian models (see e.g. Ascari and Sbordone, 2014):

$$A_t^G := \left( \int_0^1 \frac{1}{X_{f,t}} \left( \frac{P_{f,t}}{P_t} \right)^{-\varepsilon} df \right)^{-1}. \tag{1.16}$$

Because $A_t^G$ measures how efficiently resources are allocated across intermediate-goods producers, we label $A_t^G$ goods-market efficiency.

Next we consider the relationship between aggregate hours worked $H_t := \int_0^\lambda H_{i,t}\, di$ and composite labor $L_t$. With the help of (1.11), we obtain

$$L_t = \left(A_t^L\right)^{\frac{1}{1-\alpha}} H_t, \tag{1.17}$$

where we have introduced labor-market efficiency $A_t^L$ as

$$A_t^L := \left( \int_0^\lambda \left(G_{i,t}\right)^{\theta-1} \left( \frac{W_{i,t}}{W_t} \right)^{-\theta} di \right)^{-(1-\alpha)}. \tag{1.18}$$

Labor-market efficiency is, up to a monotonic transformation, the inverse of the standard measure of wage dispersion used in sticky-wage models. Labor-market efficiency describes the efficiency of the allocation of the different types of labor due to staggered wage-setting.

The aggregate production function can be written as

$$Y_t = A_t A_t^G A_t^L K_t^\alpha H_t^{1-\alpha}. \tag{1.19}$$

Thus output depends not only on exogenous aggregate productivity $A_t$, capital $K_t$, and employment $H_t$ but also on endogenous goods-market efficiency $A_t^G$ and labor-market efficiency $A_t^L$. We will call the product $A_t^G A_t^L$ aggregate efficiency in the following.

In a steady state, the aggregate production function can be conveniently expressed with the help of detrended ("∼") variables:

$$\tilde{Y} = A^G A^L \tilde{K}^\alpha H^{1-\alpha}. \tag{1.20}$$

## 1.2.3 Parameter values

The model is parameterized on a quarterly basis. Table 1.1 gives an overview over all parameter values. We follow Amano et al. (2009) by choosing an annual growth rate of aggregate productivity of 2%. The depreciation rate of capital $\delta$ is 2.5% (Ascari et al., 2018). We set the price elasticity of substitution, $\varepsilon$, to 7 (in line with Adam and Weber, 2019; Nakamura and Steinsson, 2008). The firm exit probability is estimated by Adam and Weber (2019a) to be around 2.9%. This value corresponds to the average firm birth and exit rate in U.S. firm data from the Business Dynamics Statistics (BDS). Parameter $q$ is key for the analysis in Adam and Weber (2019b). If we abstracted from wage rigidity like Adam and Weber (2019b), it would by and large determine the optimal inflation rate. As one of our paper's main findings is that deflation may be optimal, we deliberately choose a comparably large value for $q$, which tends to make it harder for our model to generate negative optimal inflation rates. As explained in more detail in Appendix 1.B, we choose an annual growth rate of 2.4%, which is among the larger values that can be supported by Adam and Weber's analysis.

We set the elasticity of substitution between different types of labor, $\theta$, to 6, which is in the range of values used in the literature, reaching from 4 to 21 (Christiano et al., 2005; Amano et al., 2009; Erceg et al., 2000). Our value corresponds to the value chosen by Ascari et al. (2018). We assume a working-life horizon of 45 years (180 periods) and that individuals start their working life at the age of 20. After retirement, at the age of 65, individuals live for another 14 years and die thereafter, which means that the life expectancy corresponds to the one in the US in 2019, i.e. before the Covid-19

| Parameter | Value | Source |
|---|---|---|
| **Aggregates** | | |
| a | $1.02^{(1-\alpha)0.25}$ | Amano et al. (2009) |
| $\delta$ | 0.025 | Ascari et al. (2018) |
| **Firm** | | |
| $\varepsilon$ | 7 | Firm Mark-up=$\frac{1}{\varepsilon-1}$, Adam and Weber (2019a), Nakamura and Steinsson (2008) |
| $d$ | 0.029 | Average of firm birth and exit rate (Adam and Weber, 2019a) |
| $\alpha$ | $\frac{1}{3}$ | Capital-output share |
| $q$ | $exp(1.024^{0.25}-1)$ | Firm productivity growth trend (see Appendix 1.B) |
| **Individuals** | | |
| $\theta$ | 6 | Ascari et al. (2018) |
| $T$ | 180 | 45 years working life |
| $TR$ | 56 | 14 years retirement |
| $g(\tau)$ | Hansen (1993) | Worker's productivity growth |
| $\beta$ | 0.99 | Standard value |
| $\eta$ | 1 | Dotsey et al. (1999); Golosov and Lucas (2007) |
| $\kappa$ | 1 | Inverse of Frisch elasticity (Amano et al., 2009) |
| **Nominal frictions** | | |
| $\phi$ | 0.55 | Adam and Weber (2019a), Coibion et al. (2012) |
| $\omega$ | 0.75 | Amano et al. (2009) |

Table 1.1: Parameter values

pandemic.[5]

For the age-dependent labor productivity profile, we use standard estimates by Hansen (1993), which are commonly used in the macroeconomic literature (see e.g. Cooley and Henriksen, 2018; İmrohoroğlu and Zhao, 2022). We normalize the productivity profile such that 20-year-old workers start their working lives with an individual productivity level of 1. Figure 1.1 shows the annualized growth rate of individual productivity. It is very high for young workers, declines as workers become older and turns negative for workers who are nearly fifty years old. As discussed in more detail in Appendix 1.C, a re-evaluation of Hansen's findings with more recent data leads to a somewhat steeper productivity-age profile for younger workers. Using this alternative profile would strengthen our finding of mild deflation being optimal.

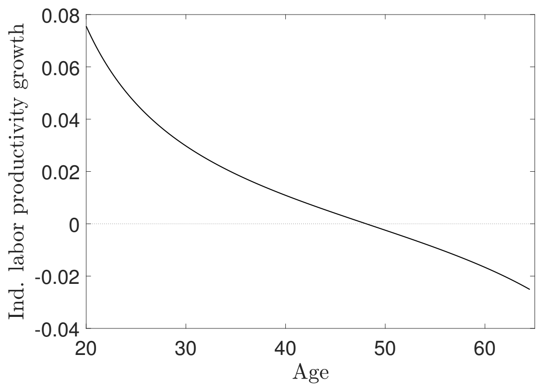



Figure 1.1: Annualized growth rate of individual labor productivity as a function of age.

At this point, we would like to note that, due to the presence of aggregate productivity growth, a negative growth rate of individual productivity does not typically imply that a worker's marginal product of labor decreases over time. As the aggregate growth rate amounts to 2%, the marginal product of labor would only decline for workers whose individual labor productivity has an annualized growth rate below $-2\%$, i.e. for workers who are very close to retirement.

We set the quarterly discount factor to 0.99. Concerning the parameters governing the disutility of labor in workers' utility, we set both $\eta$ and $\kappa$ to 1 (compare Dotsey et al., 1999; Golosov and Lucas, 2007; Amano et al., 2009). A value of $\phi = 0.55$ implies that nominal prices adjust every 7 months on average (compatible with Adam and Weber, 2019; Coibion et al., 2012). To match the empirically observed duration of wage

[5] Source: `https://genderdata.worldbank.org/`.

contracts, which is around one year, we set $\omega$ to 0.75 (see Amano et al., 2009). Finally, we note that the algorithm that is used to compute the steady states is described in Appendix 1.D.

# 1.3 Effects of Different Trend Inflation Rates

## 1.3.1 Overview

In the following, we present simulation results for steady states with different inflation rates and examine the consequences of different trend inflation rates for individual prices and wages as well as aggregate variables. We start with an analysis of the price markups of goods (Section 1.3.2) and proceed with a discussion of wage markups (Section 1.3.3). One key finding is that higher trend inflation tends to lead to substantially higher markups in the labor market. This has important consequences for aggregate employment and other aggregate variables, which are considered in Section 1.3.4. In the subsequent Section 1.3.5, we discuss the implications of trend inflation for individual uncertainty about real wages, which arises due to the Calvo friction in the labor market. Finally, we will be in a position to discuss the implications of trend inflation for different age groups.

## 1.3.2 Markups in goods markets

Before we begin our analysis of markups in goods markets and their relation to trend inflation in our full model, it is useful to consider the case of flexible prices. Because firms' productivity grows at rate $q$ as they become older, relative prices of individual firms decline at a net rate of $q^4 - 1 \approx 2.4\%$ every year under flexible prices. If the aggregate price level increases at this rate every year, the decline in relative prices can be obtained even when all firms never adjust their nominal prices. Thus, for a rate of inflation of 2.4%, sticky goods prices are not distortionary and the highest possible degree of goods-market efficiency $A^G$ can be achieved even in the presence of sticky prices (see Adam and Weber, 2019a).

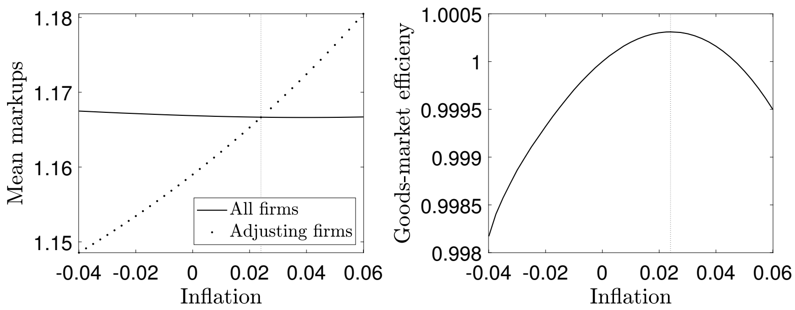



Figure 1.2: The effects of different trend inflation rates on the mean markups of all firms and adjusting firms (left panel) and on goods-market efficiency $A^G$ (right panel), where $A^G$ has been normalized to one for $\pi = 0\%$. The vertical lines in both panels mark inflation rates of 2.4%.

These results are confirmed by Figure 1.2, which shows results from our simulations for different-steady state inflation rates under sticky goods prices. The left panel shows that, for a rate of inflation of 2.4%, the markups selected by firms that can adjust their prices are equal to $\varepsilon/(\varepsilon - 1) = 7/6 \approx 1.167$, which is the markup they would choose under flexible prices. At the same time, because firms never adjust their prices when inflation is 2.4%, the mean markups of all firms and the markups of adjusting firms are identical. The right-hand side panel confirms that goods-market efficiency is highest under the inflation rate under consideration.

For inflation rates higher than 2.4%, firms have to take into account that their markups deteriorate during periods where they are unable to adjust their prices. As a consequence, the markups of firms that adjust their prices are increasing functions of inflation. There are two opposing effects on mean markups. First, as we have discussed, newly selected markups are an increasing function of inflation. Second, markups for firms that cannot adjust their prices deteriorate over time when inflation is high. On balance, both effects almost cancel and mean markups typically decrease mildly with inflation (see the left panel of Figure 1.2).

## 1.3.3 Wage markups

If there were nominal rigidities only in goods markets but not in labor markets, the results discussed in the previous section would imply an optimal rate of inflation that is slightly higher than 2.4% (in line with Adam and Weber, 2019a).[6] To examine the implications of sticky wages for our findings, it is instructive to consider a labor market with flexible wages first and to study how the real wage of an individual worker would evolve over time in this case. First, the real wage would increase as a result of aggregate growth. This effect in isolation would make a worker's wage grow at an annual rate of 2.0%. Second, one has to take into account that an individual worker's productivity changes over the life cycle. This effect would lead to high real wage growth for young workers and lower growth for older workers.

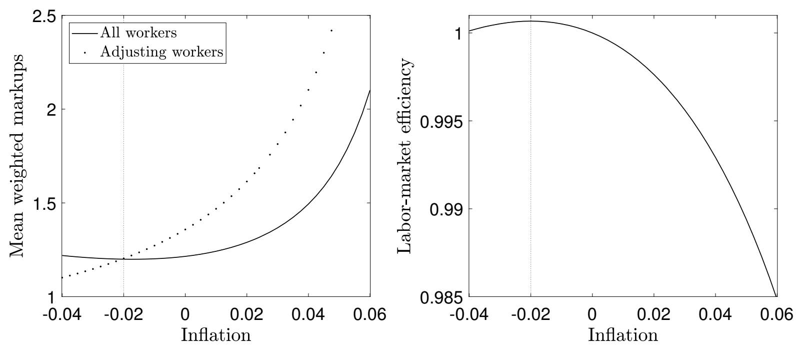



Figure 1.3: The effects of different trend inflation rates on the mean markups of all workers and adjusting workers (left panel) and on labor-market efficiency $A^L$ (right panel), where $A^L$ has been normalized to one for $\pi = 0\%$. Special case where workers' productivity does not change over the life cycle. The vertical lines in both panels mark inflation rates of $-2.0\%$

By solving our model for age-independent worker productivity, we are able to isolate the effects of aggregate growth for labor-market markups under sticky wages. The left panel of Figure 1.3 shows the wage markups of all workers and those of workers who are able to adjust their nominal wages as functions of trend inflation. At a negative inflation rate of $-2\%$, workers' real wages grow at a rate of 2% during times where they cannot change their wages. As this growth rate of real wages implies constant markups, nominal wages remain unchanged even in periods where workers could change them. Thus newly adjusted wages equal mean wages. Moreover, markups always correspond to the markups under flexible wages ($\theta/(\theta-1) = 6/5 = 1.2$). To sum up, a negative inflation rate of $-2\%$ guarantees that wage markups equal the wage markups that would prevail under flexible wages just like a positive inflation rate of 2.4% entails relative

[6]The optimal inflation would be slightly higher than 2.4% because of the monopolistic distortions in the goods markets, which are alleviated by higher trend inflation. Compare the mean markups of all firms in Figure 1.2, which decrease with trend inflation.

goods prices that emulate those under flexible prices. One would thus conjecture that, in the scenario where worker productivity does not depend on age, labor-market efficiency is highest under an inflation rate of $-2\%$. This is confirmed by the right panel of Figure 1.3.

As a next step, we turn to the full model, i.e. the more complex case where a worker's productivity depends on age. The corresponding results are displayed in Figure 1.4. The left panel focuses on young workers, who are aged 20-30 years and experience high labor-productivity growth. The panel shows the mean markups of all workers as well as all adjusting workers in this age group. The middle panel displays analogous graphs for middle-aged workers (aged 40-50), whose individual productivity growth stalls.

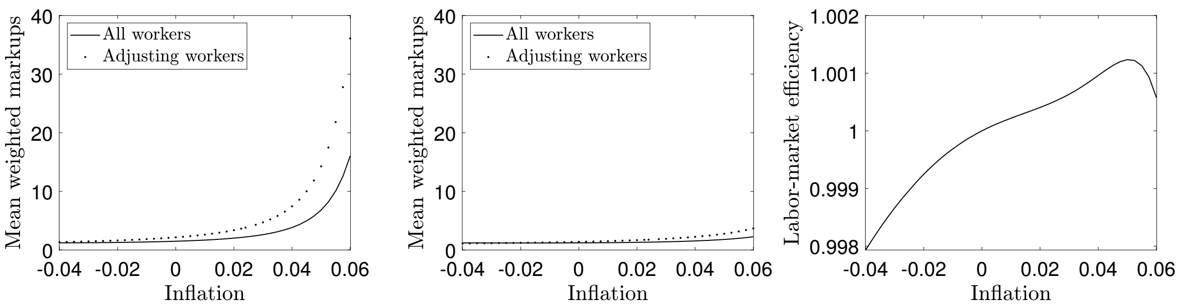



Figure 1.4: General case where workers' productivity changes over the life cycle. Left panel: the effects of different trend inflation rates on the mean markups of all young workers and adjusting young workers (aged 20-30). Middle panel: the effects of different trend inflation rates on the mean markups of all middle-aged workers and adjusting middle-aged workers (aged 40-50). Right panel: labor-market efficiency $A^L$ as a function of trend inflation; $A^L$ has been normalized to one for $\pi = 0\%$.

For the latter group of middle-aged workers, real wages would increase approximately at a rate of 2% under flexible wages, which is the growth rate of aggregate productivity. A negative inflation rate of $-2\%$ allows for real-wage growth of 2% even in the absence of nominal wage adjustments. As a consequence, mean wages and mean newly adjusted wages are approximately identical at this inflation rate, and wage markup dispersion is minimized within the group of middle-aged workers.

For young workers, real wages would grow at a substantially higher rate under flexible wages, namely at approximately 7%, which is the sum of the aggregate growth rate of 2% and a typical individual worker productivity growth rate of 5% in this age group (compare Figure 1.1). At negative inflation rates of approximately $-7\%$, which is smaller than the lowest rate of inflation displayed in the figure, nominal wages of young workers would thus be adjusted by only small amounts. This inflation rate would therefore minimize markup dispersion within this group.

The panel on the right-hand side shows that labor-market efficiency is maximized at an inflation rate of around 5%. This is due to the fact that labor-market efficiency does not only depend on markup dispersion within age groups but on the distribution of markups and productivities across age groups as well. As young workers' wage markups increase with inflation particularly strongly, high inflation rates imply that these comparably unproductive workers contribute relatively little to aggregate labor, which tends to make aggregate labor-market efficiency $A^L$ high for moderate positive inflation.

It may be worth highlighting that the changes in labor-market efficiency in response to changes in trend inflation are larger than the corresponding changes in goods-market efficiency. Moreover, mean wage markups are more strongly influenced by inflation than the markups in goods markets. As discussed in Amano et al. (2009), the strong effect of inflation on wage markups is driven by an asymmetry in the utility function of workers. Wage markups that are too low compared to the markups under flexible wages lead to substantially larger utility losses than high markups.

The strong response of wage markups to inflation is a first indication that wage rigidities may be more important than price rigidities for understanding the consequences of trend inflation in our model. The marked rise in wage markups with inflation has sizable consequences for aggregate variables, as will be studied in more detail in the next section.

### 1.3.4 Aggregate variables

How key aggregate variables are affected by different trend inflation rates is shown in Figure 1.5. Aggregate efficiency, which is shown in the left panel of the first row, is the product of goods-market efficiency and labor-market efficiency. We have seen that goods-market efficiency has its maximum at 2% inflation (see Figure 1.2) and labor-market efficiency takes its highest value at inflation between 4% and 5%. As changes in labor-market efficiency are large around its maximum and goods-market efficiency is relatively flat around its maximum, the maximum of aggregate efficiency is located close to the maximum of labor-market efficiency at an inflation rate somewhat larger than 4%.

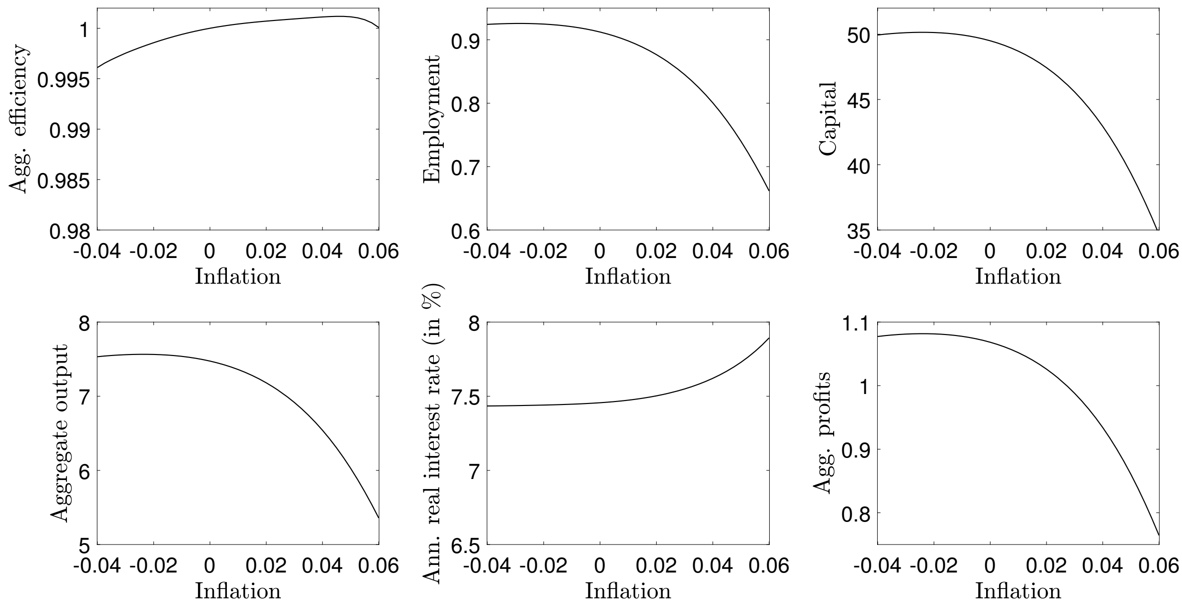



Figure 1.5: Aggregate variables for different trend inflation rates. First row: Aggregate efficiency (normalized to one at $\pi = 0\%$), aggregate hours worked, aggregate capital. Second row: output, annualized real interest rate, profits.

Section 1.3.3 has demonstrated that mean wage markups increase substantially with inflation. As a consequence, employment decreases quite strongly for higher rates of inflation (see the middle panel of the first row). The low levels of employment decrease the marginal product of capital and thus also the amount of capital rented by firms when inflation is high (see the right panel in the first row). The level of aggregate output as a function of inflation is dominated by the changes in employment and capital and hardly affected by the comparably modest changes in aggregate efficiency. As a result, aggregate output decreases substantially for higher inflation rates (see the left panel of the second row).

To lay the grounds for our analysis of the effects of changes in trend inflation for different age groups, it is instructive to examine changes in real interest rates and aggregate profits (see the middle and right panel in the second row of Figure 1.5). Real interest rates increase with inflation. This is due to the effect that high inflation rates imply high wage markups and thus high real wages. High real wages make it attractive for firms to substitute labor for capital to some extent, which tends to drive up real interest rates as well. As we will see, higher real interest rates are particularly attractive for retirees as they only receive capital income. Finally, we also observe that aggregate profits move more or less in lockstep with aggregate output. This is plausible because mean goods-markets markups are hardly affected by changes in inflation and thus profits are approximately proportional to aggregate sales or aggregate output (see Figure 1.2). Changes in profits will be important for understanding the impact of permanent changes in inflation on stock prices, which will be considered in Section 1.5.

### 1.3.5 Individual uncertainty

In the course of our analysis, we have emphasized that nominal wage rigidity is more important for understanding the consequences of trend inflation for aggregate economic variables than nominal price rigidities. There is a difference between sticky wages and sticky prices that we have not explored yet. Staggered wage adjustment causes uncertain individual labor incomes and thereby represents a source of uncertainty for individual workers whereas staggered price adjustment does not.

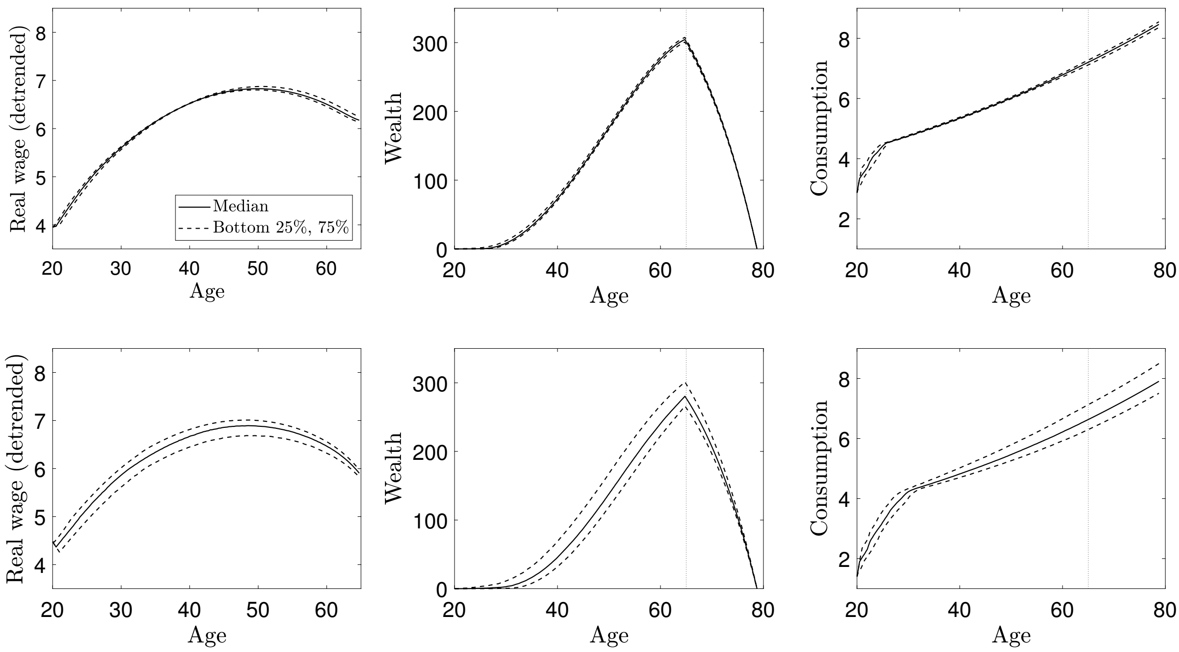



Figure 1.6: Quartiles of the distributions of individual real wages, wealth, and consumption for different age groups. First row: −3% inflation. Second row: +3% inflation.

Figure 1.6 shows quartiles of the distributions of detrended real wages, wealth, and consumption for different age groups. We focus on two cases: deflation with an inflation rate of −3% and moderate inflation of 3%. Under deflation, real wages grow at a rate of roughly 3% when workers do not adjust their wages. As middle-aged workers' productivity increases approximately at this rate, wages are changed by only small amounts if workers have the opportunity to adjust them. As a result, the distribution of wages under deflation is relatively tight for workers around the age of 40. For very young workers, productivity growth, which is the sum of aggregate growth $a$ and the age-specific change in productivity, is higher and above the 3% real wage growth caused by an inflation rate of $-3\%$. This requires larger wage adjustments when young workers are able to change their wages and leads to a moderately larger wage dispersion within groups of identical age. In a similar vein, very old workers' productivity grows at a rate lower than 3%, which leads to wage dispersion as well.

Under an inflation rate of 3%, wages are substantially more dispersed across members of younger age groups compared to deflation. This follows from the substantial drops in real wages during periods of constant nominal wages, which induce younger workers to change their wages by large amounts whenever adjustments are possible. The dispersion of wages within groups of a specific age is comparably high even for old workers aged around 60.

The larger dispersion of real wages under inflation has important consequences for the distributions of wealth and consumption among individuals of a specific age. The more dispersed real wages under high inflation lead to more dispersed incomes and thus more dispersed levels of wealth and consumption. Thus inflation causes much more individual uncertainty than deflation. Uncertain incomes are particularly harmful to young workers, who cannot borrow in order to dampen the consequences of low current incomes for current consumption.

Finally, we discuss how inflation affects the median levels of wages, wealth, and consumption of different age groups. Figure 1.6 shows that inflation influences the median level of consumption for young workers in particular. As has been demonstrated before, high inflation makes young individuals choose high wage markups as they have to factor in the possibility of declining real wages during periods of fixed nominal wages. This is also visible from the panels in the first column, which shows that young workers' real wages tend to be higher under inflation compared to deflation. High real wages tend to lead to low incomes and therefore low levels of consumption. For instance, in the presence of inflation, the consumption levels of 20-year-old workers are reduced to less than one-half of what they are under deflation.

### 1.3.6 Preferences over trend inflation rates

Having discussed the consequences of inflation for various economic variables, we are now in a position to analyze which inflation rates would be preferred by different age groups. We will present a thorough analysis of transition dynamics in Section 1.5. At this point, we propose a comparably simple thought experiment. Consider an economy in a steady state with zero inflation. For each individual in this economy, we then ask which inflation rate from −4% to 6% would deliver the highest utility if the individual could, for given individual wage and wealth, move to an economy that is in the steady state with this different trend inflation rate but is identical with regard to all other exogenous parameters. For each age group, we then compute the median preferred inflation rate.

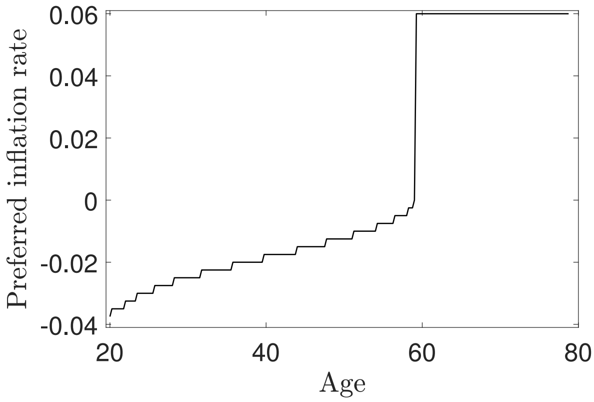



Figure 1.7: Median preferred inflation rates for different age groups (individual state variables drawn from distribution in the steady state with 0% inflation). Inflation rates under consideration: −4.00%, −3.75%, −3.50%, ..., 5.75%, 6.00%

The median preferred inflation rates as a function of age are displayed in Figure 1.7. In line with our previous analysis, 20-year-old workers prefer deflation with negative inflation rates of −3.75%. Because workers' productivity growth is a decreasing function of age, older workers tend to prefer higher inflation rates. Individuals older than 60 years, who are retirees or at least close to retirement, are mainly interested in high real interest rates. As real interest rates increase with inflation, they prefer the highest inflation rate that we consider in this exercise.

As a next step, we study which inflation rate is socially optimal. For this purpose, we compare steady states and apply two different welfare measures. As a first measure, we employ the lifetime utility of the youngest individuals, who enter the economy. It may be important to note that all members of this group are identical, as opposed to older individuals, where wages and wealth differ across individuals of identical age. The socially optimal inflation rate in this case is identical to the inflation rate that is preferred by workers aged 20 in the previous thought experiment. Thus, according to our first welfare measure, deflation with an inflation rate of −3.75% is socially optimal.

Our second welfare measure corresponds to the mean of the instantaneous utilities of all individuals who are alive in a particular period in the steady state. This measure of welfare is similar in spirit to the unconditional expectation of a representative consumer's utility (or, equivalently, the unconditional loss), which is often used in new Keynesian models (see e.g. Rotemberg and Woodford, 1997, for an early contribution).

| | lifetime utility at $\tau = 1$ | | avg. current utility | |
|---|---|---|---|---|
| Case | Opt. infl. | Welf. loss | Opt. infl. | Welf. loss |
| Main model | −3.75% | −3.65% | −3.00% | −2.30% |
| No wage stickiness $\omega = 0$ | +2.75% | −0.06% | +2.75% | −0.07% |
| No price stickiness $\phi = 0$ | −4.00% | −3.90% | −3.25% | −2.49% |
| No firm growth $q = 1$ | −4.00% | −3.77% | −3.25% | −2.40% |
| No ind. labor growth $g(\tau) = 1$ | −1.75% | −0.61% | −1.75% | −0.64% |
| Agg. growth $a = 1.01^{(1-\alpha)0.25}$ | −2.75% | −1.85% | −2.00% | −0.99% |
| No agg. growth $a = 1$ | −2.00% | −0.74% | −0.75% | −0.09% |
| Frisch elasticity $\kappa^{-1} = 2$ | −3.50% | −1.90% | −2.75% | −1.14% |
| Elasticity of sub. labor $\theta = 4$ | −3.00% | −0.94% | −2.50% | −0.38% |

Table 1.2: Optimal steady-state inflation rates and the consumption-equivalent welfare losses implied by 0% inflation rather than the optimal inflation rates. Two welfare measures are considered: the expected lifetime utility of individuals who enter the economy at the youngest possible age and the mean instantaneous utility of all individuals currently alive.

Table 1.2 shows the socially optimal inflation rates for both welfare measures and different variants of our model, where we consider a grid of inflation rates with a step size of 0.25 percentage points. The welfare loss refers to zero inflation as opposed to the socially optimal level and is measured in consumption equivalents. Our first observation is that our second welfare measure tends to lead to higher optimal trend inflation. This is plausible because, in line with our previous analysis, younger individuals typically prefer lower negative inflation rates than older individuals. The second welfare measure puts more weight on the utility of older individuals, which results in higher optimal rates of inflation.

In Table 1.2, we also provide the findings for a scenario without wage stickiness. In this case, we obtain results analogous to Adam and Weber (2019a), who find that positive inflation rates are optimal under sticky prices if individual firms become more productive over time and firms' relative prices should decrease accordingly. The socially optimal inflation rate in the case considered here is even a bit higher than the growth rate of firm productivity. This is due to the fact that higher inflation leads to lower mean markups and thus alleviates the distortions from monopolistic competition (compare Figure 1.2).[7] A point worth noting is that, in the absence of wage stickiness, the welfare losses, measured in consumption equivalents, are comparably small if an inflation rate of zero rather than the socially optimal inflation rate is chosen.

Table 1.2 also shows that scenarios that abstract from sticky goods prices or from increases in firm productivity with firm age lead to lower optimal rates of inflation than the main variant of our model. This is to be expected as in these variants of our model the effects in Adam and Weber (2019a) that lead to positive optimal inflation rates are absent. It may be worth stressing that the differences in optimal trend inflation between these variants and our main model are comparably small. Hence the finding in Amano et al. (2009) that wage stickiness is more important than price stickiness for understanding the effects of trend inflation extends to our framework with age-dependent worker productivity.

A unique feature of our analysis of trend inflation is the age-dependent productivity of workers. Table 1.2 shows that this feature has non-negligible effects. The particularly high productivity growth for young workers causes optimal inflation to be substantially lower in our main model compared to the scenario where productivity does not depend on the age of a worker.

Next we examine the consequences of aggregate growth for optimal inflation. This exercise is relevant as the long-term growth rate has declined in many economies and may well remain low in the future (see e.g. Kose and Ohnsorge, 2023). Lower growth makes higher inflation rates optimal. This can be explained by noting that lower aggregate growth also leads to lower increases in worker productivity over time. Lower growth in worker productivity makes the automatic increases in real wages that are brought about by deflation less important.

Finally, it appears important to assess the robustness of our findings to changes in two key parameters that affect wages and hours worked, namely the Frisch elasticity

[7] The monopolistic distortion in goods markets is shut off by Adam and Weber (2019a) with the help of a sales subsidy.

and the elasticity of substitution for different types of labor. Table 1.2 shows that the optimal inflation rates are somewhat higher for a higher Frisch elasticity and a smaller elasticity of substitution between different kinds of labor. Under a lower elasticity of substitution, welfare losses from an inflation rate of zero percent are comparably small. This appears plausible because a less elastic labor demand makes low real wages after longer periods of fixed nominal wages less costly for young workers.

## 1.4 Downward Nominal Wage Rigidity

According to a classic argument (see Tobin, 1972, for example), moderate inflation may be desirable as it "greases the labor market's wheels" in the presence of downward nominal wage rigidity (DNWR). It is thus interesting to examine the robustness of our findings to the introduction of DNWR. To sharpen our results, we focus on the following polar case, which provides us with an upper bound on the effects of DNWR in our model. As before, nominal wages have to remain unchanged with probability $\omega$ in every period. With probability $1-\omega$, they can be adjusted upwards but not downwards. Nominal wages of individual workers can never drop.

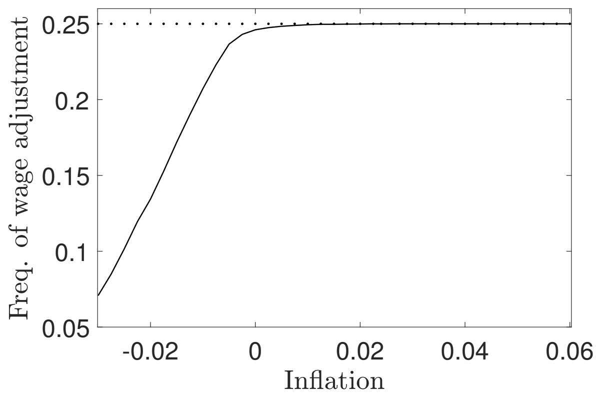



Figure 1.8: The frequency of wage adjustment under downward nominal wage rigidity as a function of trend inflation.

In the standard scenario considered in the previous section, $\omega$ is chosen such that the expected duration of a wage contract is one year, which corresponds to a value often found empirically (see Amano et al., 2009, for a discussion). At a typical inflation rate of two percent, one can show that nominal wages never decline in our main model without DNWR. Under an inflation of 2%, the value for $\omega = 0.75$ chosen in Section 1.2.3

thus guarantees an empirically plausible contract duration of one year in the presence of DNWR as well. Figure 1.8 plots the frequency of wage adjustment for different trend inflation rates. In line with our previous discussion, an inflation rate of 2% results in a frequency of wage adjustment that equals $1 - \omega = 0.25$. For sufficiently low inflation rates, the downward constraint on nominal wages becomes binding in some cases and the frequency of wage adjustment is lower than 0.25.

When inflation is negative, DNWR causes real wages to increase invariably as workers grow older. Under negative inflation rates, DNWR thus represents a particularly serious constraint for old workers, whose individual productivities decrease with age. The differential effects of deflation and inflation on real wages for different age groups can be seen from the two panels on the left-hand side of Figure 1.9, which show the quartiles of the distributions of detrended real wages for different age groups. The top panel on the left displays the results for an inflation rate of $-3\%$, the bottom panel displays our findings for a rate of 3%. Inflation does indeed grease the labor market's wheels. Compared to deflation, age-specific detrended wages are much more in line with individual worker productivity, which is a hump-shaped function of age.

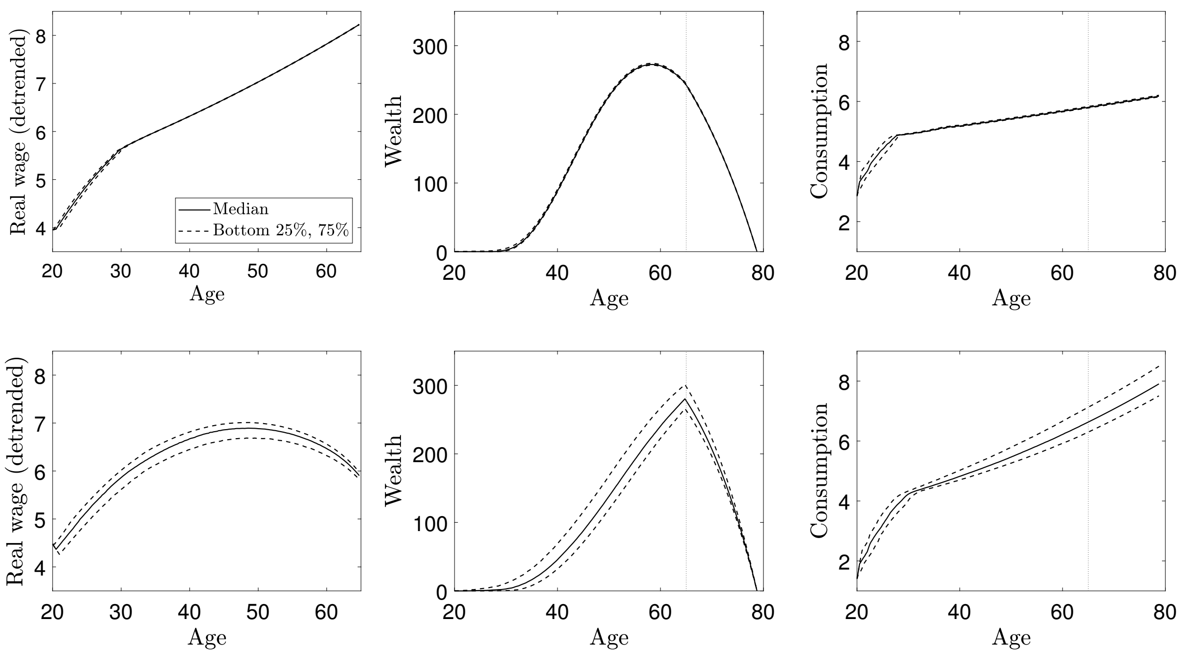



Figure 1.9: Quartiles of the distributions of individual real wages, wealth, and consumption for different age groups under DNWR. First row: $-3\%$ inflation. Second row: $+3\%$ inflation.

The high real wages for older workers under deflation result in a low demand for their labor and therefore comparably low labor incomes. This implies that the maximum level of wealth is attained earlier in workers' lives because they start dissaving already before retirement (see the top middle panel). The two panels on the right-hand side enable a comparison of age-specific consumption levels for inflation rates of −3% and +3%. They reveal that, compared to inflation, deflation entails higher consumption of young workers, which is in line with our analysis where nominal wages can adjust downward.

As a next step, we examine the effects of different levels of inflation for aggregate variables. As can be confirmed by comparing Figure 1.10 with Figure 1.5, DNWR has no consequences for aggregate variables when inflation is above 1%. As discussed before, deflation makes DNWR a binding constraint for older workers. For sizable negative rates of inflation, this constraint affects middle-aged workers as well. Thus rates of inflation below −2% have a number of detrimental effects. First, they entail low levels of aggregate efficiency. The labor of older workers is too costly, which leads to inefficiently low levels of employment in this group. Second and as a consequence, aggregate employment is low. Third, low labor incomes result in less savings and therefore a low level of capital. Fourth, low levels of efficiency, employment and capital result in low levels of output and profits.

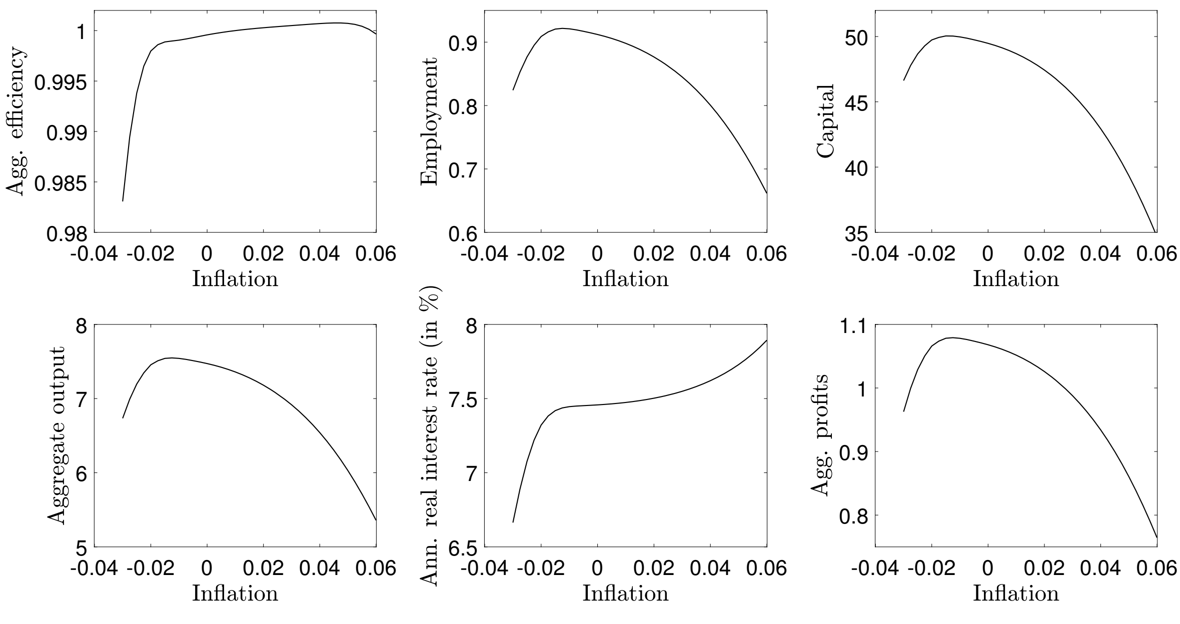



Figure 1.10: Aggregate variables for different trend inflation rates under DNWR. First row: Aggregate efficiency (normalized to one at $\pi = 0\%$), aggregate hours worked, aggregate capital. Second row: output, annualized real interest rate, profits.

Finally, we analyze preferences over steady-state inflation rates as in Section 1.3.6.

According to Figure 1.11, the general pattern that workers, in particular young ones, prefer deflation and that retirees prefer inflation is robust to the introduction of DNWR. In line with the additional, adverse effects of low and negative rates of inflation under DNWR, workers prefer higher rates of inflation than without DNWR but the most preferred rates are still negative. The median preferred inflation rate is thus higher and amounts to $-1.0\%$. Both welfare measures that were examined in the previous section, i.e. the lifetime utility of the youngest individuals as well as the mean of the instantaneous utilities of all individuals, lead to a more moderate yet still negative inflation rate of $-1.5\%$.

To sum up, our main finding that the combination of sticky wages and age-specific productivity of workers make mild deflation optimal in a framework that would otherwise call for moderate positive inflation rates is robust to the inclusion of DNWR. While a framework with idiosyncratic shocks to worker productivity might tend to make higher rates of inflation desirable, one also has to take into account that, in another dimension, we have stacked the deck against deflation by introducing a very strict form of DNWR, where nominal wage cuts are completely impossible. Milder forms of DNWR would plausibly entail lower socially optimal rates of inflation.

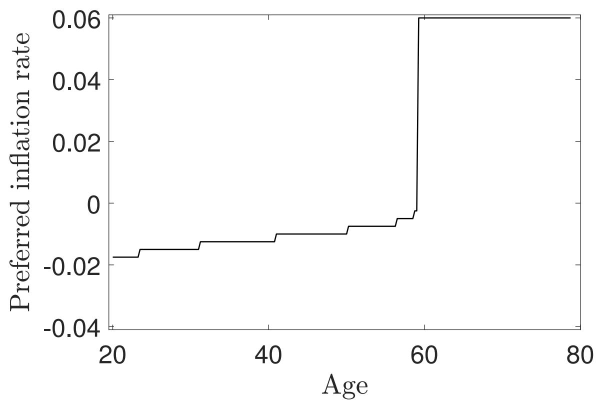



Figure 1.11: Median preferred inflation rates for different age groups under DNWR (individual state variables drawn from distribution in the steady state with 0% inflation). Inflation rates under consideration: $-4.00\%$, $-3.75\%$, $-3.50\%$, ..., 5.75%, 6.00%

# 1.5 Politico-economic Equilibrium

In this section, we analyze transition dynamics in the economy without DNWR as well as the inflation rate that would be selected by the political process. In particular, we consider the following situation. The economy is in a steady state before period 0. At the beginning of period 0, before workers know whether they are able to adjust their wages in this period, a change in trend inflation is put to a vote, where the central bank's change in policy would be so strong such that the new level of trend inflation would be attained immediately. After this change, there would be no further changes in inflation and the economy would eventually converge to the new steady state. The possibility to change trend inflation is completely unexpected before period 0.

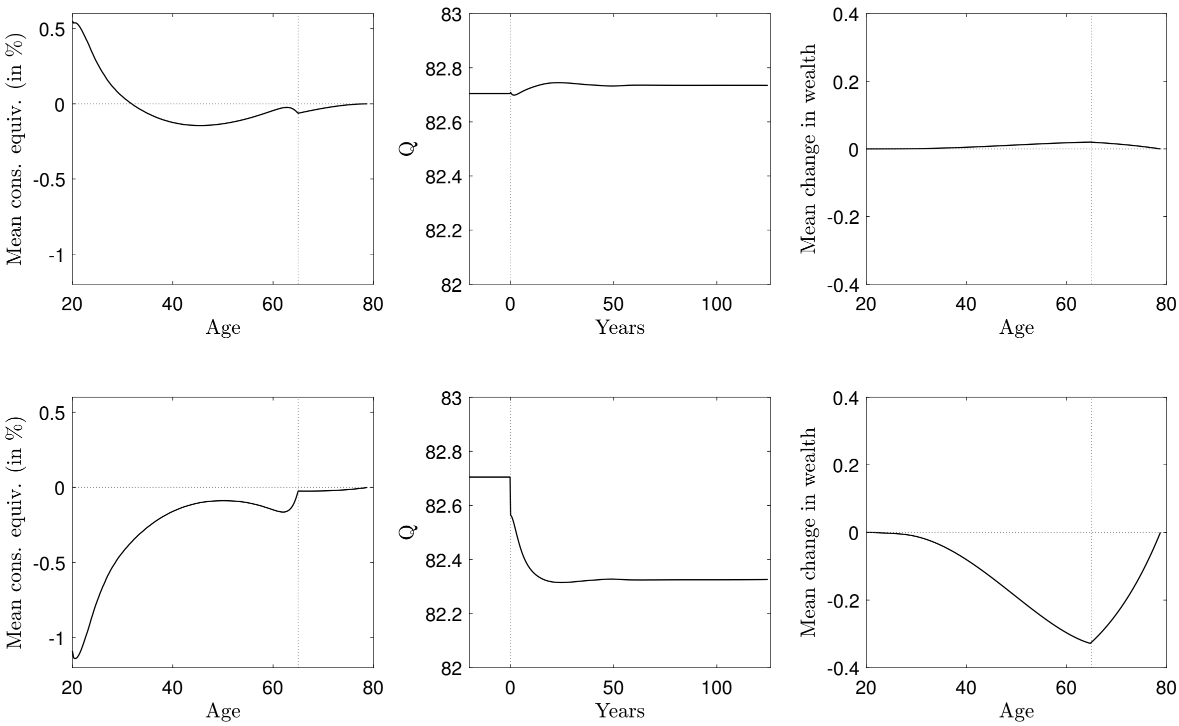



Figure 1.12: Consequences of a change in trend inflation. First row: transition from −2% to −3%. Second row: transition from −2% to −1%. First column: mean change in individuals' lifetime utility, measured in consumption equivalents, for different age groups if trend inflation was changed to the new level. Second column: transition paths for stock prices in response to an unexpected and permanent change in inflation in period 0. Third column: mean change in individuals' wealth in period 0 for different age groups.

We call a politico-economic equilibrium a situation where a majority of individuals prefer the status quo to both an increase and a decrease in trend inflation in period 0. We consider a grid of possible inflation rates, i.e. $-4\%$, $-3\%$, $-2\%$, ..., $5\%$, and $6\%$. Our simulations reveal that the unique politico-economic equilibrium involves an inflation rate of $-2\%$. At this level of deflation, most individuals, except for workers before the beginning of their thirties, are against lowering inflation further, and all individuals oppose higher inflation. This is illustrated in the first column of Figure 1.12, which shows the utility changes, measured in consumption equivalents, as a function of age for a decrease in inflation to $-3\%$ and for an increase to $-1\%$.

Young workers tend to prefer very low rates of inflation for reasons that we have discussed before. Young workers' individual productivities increase more strongly over time compared to the productivities of older workers. Low negative rates of inflation make real wages increase over time automatically even when nominal wages are fixed. This is desirable for young workers as it allows them to choose relatively low wage markups, which leads to high labor income on average. Moreover, the automatic increase in real wages caused by deflation entails smaller changes in nominal wages whenever such changes are possible. Hence individual uncertainty is low for young workers.

One mechanism that has not been discussed so far is the discontinuous change in stock prices brought about by unexpected changes in trend inflation. The time path of stock prices is shown in the second column of Figure 1.12. While a change from an inflation rate of $-2\%$ to $-3\%$ only leads to a negligible jump in stock prices, the change from $-2\%$ to $-1\%$ induces a comparably sizable drop. This drop is compatible with the fact that, compared to an inflation rate of $-2\%$, an inflation rate of $-1\%$ entails roughly the same price markups but lower output and thus smaller profits in the long run (see Figure 1.5). While all individuals invest identical shares of their wealth into stocks as opposed to physical capital, the drop in stock prices affects individuals close to the retirement age of 65 years most strongly because these individuals are the wealthiest.

The utility changes of retirees and workers close to retirement are also affected by changes in real interest rates. This explains why these individuals oppose a drop of inflation to $-3\%$. This drop would lead to moderate gains in wealth but would come at the cost of lower real interest rates in the long run (compare Figure 1.5). Lower interest rates are harmful to this group of individuals, for whom wealth rather than labor is the most important source of income.

## 1.6 Conclusions

This paper has revisited the question of which level of inflation central banks should target. Our model incorporates sticky prices and firm-specific productivity growth. Taken together, these factors have been shown to lead to positive optimal inflation rates of around 2% (Adam and Weber, 2019a; Adam et al., 2022). In addition, our model includes the key ingredients from Amano et al. (2009), namely aggregate productivity growth and sticky wages, which tend to make deflation optimal. We show that the effects making deflation desirable are strengthened substantially by an additional element: age-specific worker productivity. Overall our analysis has revealed that the effects that tend to lead to low and even negative optimal inflation rates outweigh those that make positive inflation optimal. This finding even holds under an arguably extreme form of downward nominal wage rigidity.

Our framework has also highlighted conflicts of interest between generations. As the productivity of young workers grows at a high rate, they benefit strongly from deflation. Inflation would require high markups on average as sticky nominal wages pose the risk of real markups that are substantially below their desired levels, which would be very costly to workers. Deflation causes real wages to grow automatically and roughly in line with productivity and is thus desirable.

While older workers and retirees do not benefit from deflation as much as young workers, they still oppose transitions from inflation rates of $-2\%$ to higher levels. This is due to the fact that increases in inflation tend to lead to a drop in stock prices, which affects the relatively wealthy individuals the most. As a consequence, the political process leads to inflation rates of $-2\%$, which is higher than the socially optimal one. Our analysis has thus discovered a source of inflation bias that is different from the traditional one that is associated with time-inconsistent policies (Kydland and Prescott, 1977; Barro and Gordon, 1983).

Currently, no central bank intends to target a negative inflation rate of $-3.75\%$. There are two main reasons. First, official measures of inflation are biased upwards. According to recent estimates by Braun and Lein (2021), the bias can be sizable, namely 2.6 percentage points on average and even 3.7 percentage points in the wake of large shocks to relative prices. In the presence of such a measurement bias, the optimal inflation rate suggested by our analysis would correspond to a relatively mild deflation rate of around $-1\%$. Second, central banks are concerned about the effective lower bound for nominal interest rates. Positive inflation targets entail higher nominal interest rates and thus ensure that nominal interest rates are sufficiently far away from the lower bound. As argued before, the ongoing trend towards cashless societies may well render the effective lower bound substantially less relevant in the future. As a consequences, the case for mild deflation may be more compelling in the future.

# References to chapter 1

Abbritti, M., A. Consolo, and S. Weber (Dec. 2021). “Endogenous growth, downward wage rigidity and optimal inflation”. *ECB Working Paper Series No. 2635*.

Adam, K., E. Gautier, S. Santoro, and H. Weber (2022a). “The Case for a Positive Euro Area Inflation Target: Evidence from France, Germany and Italy”. *Journal of Monetary Economics* 132, pp. 140–153.

Adam, K. and H. Weber (2019a). “Optimal Trend Inflation”. *American Economic Review* 109(2), pp. 702–737.

Adam, K. and H. Weber (Sept. 2019b). “Price Trends over the Product Life Cycle and the Optimal Inflation Target”. *Bundesbank Discussion Paper 32/2019*.

Amano, R., K. Moran, S. Murchison, and A. Rennison (2009). “Trend Inflation, Wage and Price Rigidities, and Productivity Growth”. *Journal of Monetary Economics* 56(3), pp. 353–364.

Ascari, G., L. Phaneuf, and E. Sims (2018). “On the Welfare and Cyclical Implications of Moderate Trend Inflation”. *Journal of Monetary Economics* 99, pp. 56–71.

Ascari, G. and A. M. Sbordone (2014). “The Macroeconomics of Trend Inflation”. *Journal of Economic Literature* 52(3), pp. 679–739.

Auclert, A., B. Bardóczy, and M. Rognlie (2023). “MPCs, MPEs, and Multipliers: A Trilemma for New Keynesian models”. *Review of Economics and Statistics* 105(3), pp. 700–712.

Barro, R. and D. B. Gordon (1983). “A Positive Theory of Monetary Policy in a Natural Rate Model”. *Journal of Political Economy* 91(4), pp. 589–610.

Basu, S. and C. L. House (2016). “Allocative and Remitted Wages: New Facts and Challenges for Keynesian Models”. In: *Handbook of Macroeconomics*. Vol. 2, pp. 297–354.

Bielecki, M., M. Brzoza-Brzezina, and M. Kolasa (2022). “Intergenerational Redistributive Effects of Monetary Policy”. *Journal of the European Economic Association* 20(2), pp. 549–580.

Björklund, M., M. Carlsson, and O. Nordström Skans (2019). “Fixed-wage Contracts and Monetary Non-neutrality”. *American Economic Journal: Macroeconomics* 11(2), pp. 171–92.

Blanco, A. (2021). “Optimal Inflation Target in an Economy with Menu Costs and a Zero Lower Bound”. *American Economic Journal: Macroeconomics* 13(3), pp. 108–141.

Braun, R. and S. M. Lein (2021). “Sources of Bias in Inflation Rates and Implications for Inflation Dynamics”. *Journal of Money, Credit and Banking* 53(6), pp. 1553–1572.

Broer, T., N.-J. Harbo Hansen, P. Krusell, and E. Öberg (2020). “The New Keynesian Transmission Mechanism: A Heterogeneous-Agent Perspective”. *Review of Economic Studies* 87(1), pp. 77–101.

Christiano, L. J., M. Eichenbaum, and C. L. Evans (2005). “Nominal Rigidities and the Dynamic Effects of a Shock to Monetary Policy”. *Journal of Political Economy* 113(1), pp. 1–45.

Coibion, O., Y. Gorodnichenko, and J. Wieland (2012). “The Optimal Inflation Rate in New Keynesian Models: Should Central Banks Raise Their Inflation Targets in Light of the Zero Lower Bound?” *Review of Economic Studies* 79(4), pp. 1371–1406.

Cooley, T. and E. Henriksen (2018). “The demographic deficit”. *Journal of Monetary Economics* 93, pp. 45–62.

Diercks, A. M. (June 2017). “The Reader’s Guide to Optimal Monetary Policy”. *Available at SSRN 2989237*.

Dotsey, M., R. G. King, and A. L. Wolman (1999). “State-dependent Pricing and the General Equilibrium Dynamics of Money and Output”. *Quarterly Journal of Economics* 114(2), pp. 655–690.

Erceg, C. J., D. W. Henderson, and A. T. Levin (2000). “Optimal Monetary Policy with Staggered Wage and Price Contracts”. *Journal of Monetary Economics* 46(2), pp. 281–313.

Fischer, S. (1981). “Towards an Understanding of the Costs of Inflation: II”. *Carnegie-Rochester Conference Series on Public Policy*. Vol. 15, pp. 5–41.

Gertler, M., C. Huckfeldt, and A. Trigari (2020). "Unemployment Fluctuations, Match Quality, and the Wage Cyclicality of New Hires". *Review of Economic Studies* 87(4), pp. 1876–1914.

Golosov, M. and R. E. J. Lucas (2007). "Menu Costs and Phillips Curves". *Journal of Political Economy* 115(2), pp. 171–199.

Gonzalez-Eiras, M. and D. Niepelt (2008). "The Future of Social Security". *Journal of Monetary Economics* 55(2), pp. 197–218.

Hahn, V. (2022). "Price Dispersion and the Costs of Inflation". *Journal of Money, Credit, and Banking* 54(2-3), pp. 459–491.

Hansen, G. D. (1993). "The cyclical and secular behaviour of the labour input: Comparing efficiency units and hours worked". *Journal of Applied Econometrics* 8(1), pp. 71–80.

İmrohoroğlu, A. and K. Zhao (2022). "Rising wealth inequality: Intergenerational links, entrepreneurship, and the decline in interest rate". *Journal of Monetary Economics* 127, pp. 86–104.

Kim, J. and F. J. Ruge-Murcia (2009). "How much inflation is necessary to grease the wheels?" *Journal of Monetary Economics* 56(3), pp. 365–377.

Kose, M. A. and F. Ohnsorge (May 2023). "Slowing Growth: More Than a Rough Patch". *MPRA Paper No. 117327.*

Kudlyak, M. (2014). "The cyclicality of the user cost of labor". *Journal of Monetary Economics* 68, pp. 53–67.

Kydland, F. E. and E. C. Prescott (June 1977). "Rules Rather than Discretion: The Inconsistency of Optimal Plans". *Journal of Political Economy* 85(3), pp. 473–492.

Lucas, R. E. (1981). "Discussion of: Stanley Fischer, "Towards an understanding of the costs of inflation: II"". *Carnegie-Rochester Conference Series on Public Policy.* Vol. 15, pp. 43–52.

Nakamura, E. and J. Steinsson (2008). "Five Facts about Prices: A Reevaluation of Menu Cost Models". *Quarterly Journal of Economics* 123(4), pp. 1415–1464.

Pallotti, F., G. Paz-Pardo, J. Slacalek, O. Tristani, and G. L. Violante (Nov. 2023). "Who bears the costs of inflation? Euro area households and the 2021–2022 shock". *NBER Working Paper Series No. 31896.*

Riboni, A. and F. J. Ruge-Murcia (2010). "Monetary Policy by Committee: Consensus, Chairman Dominance, or Simple Majority?" *Quarterly Journal of Economics* 125(1), pp. 363–416.

Rotemberg, J. J. and M. Woodford (1997). “An Optimization-Based Econometric Model for the Evaluation of Monetary Policy”. *NBER Macroeconomics Annual* 12, pp. 297–346.

Schmitt-Grohé, S. and M. Uribe (2010). “The Optimal Rate of Inflation”. In: *Handbook of Monetary Economics*. Ed. by S.-C. Kolm and J. M. Ythier. Vol. 3. Elsevier Science B.V., Amsterdam. Chap. 13, pp. 653–722.

Tobin, J. (1972). “Inflation and Unemployment”. *American Economic Review*, pp. 1–18.

# Appendix to chapter 1

## 1.A Bellman Equations

### 1.A.1 Overview

In the following, we specify the optimization problems of intermediate-goods producers and households in a steady state. The optimization problems for the transition dynamics are straightforward extensions. Obviously, the optimization problems during a transition have to take into account that the aggregate variables as well as the distributions of wages and prices change over time.

### 1.A.2 Optimization problem of the intermediate-goods producers

Recall that variables with a "$\sim$" are variables that are detrended by dividing them by $\left(a^{\frac{1}{1-\alpha}}\right)^t$. Accordingly, we write $\widetilde{Y}_t = Y_t\left(a^{\frac{1}{1-\alpha}}\right)^{-t}$ and $\widetilde{w}_t = w_t\left(a^{\frac{1}{1-\alpha}}\right)^{-t}$, where $w_t$ is the composite real wage $W_t/P_t$. Moreover, we introduce $p_{f,t} = \frac{P_{f,t}}{P_t}$.

In a steady-state, detrended profits $\widetilde{\Pi}_{i,t}$ can be written as

$$\widetilde{\Pi}_{i,t} = p_{f,t}^{-\varepsilon}\widetilde{Y}\left(p_{f,t} - \frac{1}{X_{f,t}}\frac{r^\alpha \widetilde{w}^{1-\alpha}}{\alpha^\alpha(1-\alpha)^{1-\alpha}}\right), \tag{1.21}$$

where $\frac{1}{X_{f,t}}\frac{r^\alpha \widetilde{w}^{1-\alpha}}{\alpha^\alpha(1-\alpha)^{1-\alpha}}$ is firm $f$'s marginal cost, provided that it uses an optimal capital-labor ratio:

$$\frac{\widetilde{K}_f}{L_f} = \frac{\alpha}{1-\alpha}\frac{\widetilde{w}}{r} \tag{1.22}$$

With probability $1-\phi$, firms can choose their optimal prices. In this case, the value function $V^F_{adj}(X_{f,t})$ satisfies:

$$\begin{aligned} V^F_{adj}(X_{f,t}) = \max_{p_{f,t}} \Bigg\{ & p_{f,t}^{-\varepsilon}\widetilde{Y}\left(p_{f,t} - \frac{1}{X_{f,t}}\frac{r_t^{\alpha}\widetilde{w}_t^{1-\alpha}}{\alpha^{\alpha}(1-\alpha)^{1-\alpha}}\right) \\ & + (1-d)\frac{a^{\frac{1}{1-\alpha}}}{1+r_{t+1}-\delta}\mathbb{E}_t V^F(p_{f,t+1}, X_{f,t+1})\Bigg\} \\ \text{s.t. } X_{f,t+1} &= qX_{f,t}, \\ p_{f,t+1} &= p_{f,t}/\pi, \\ \mathbb{E}_t V^F(p_{f,t+1}, X_{f,t+1}) &= \phi V^F_{nadj}(p_{f,t+1}, X_{f,t+1}) + (1-\phi)V^F_{adj}(X_{f,t+1}), \end{aligned} \tag{1.23}$$

where "adj" stands for the possibility to adjust ones price. The subscript "nadj" describes situations where firms cannot adjust their prices. If a firm cannot adjusts its nominal price in period $t+1$, its relative price is the previous period's relative price, divided by inflation: $p_{f,t+1} = \frac{p_{f,t}}{\pi}$

For firms that cannot adjust their prices, the value function satisfies

$$\begin{aligned} V^F_{nadj}(p_{f,t}, X_{f,t}) = & p_{f,t}^{-\varepsilon}\widetilde{Y}\left(p_{f,t} - \frac{1}{X_{f,t}}\frac{r^{\alpha}\widetilde{w}^{1-\alpha}}{\alpha^{\alpha}(1-\alpha)^{1-\alpha}}\right) \\ & + (1-d)\frac{a^{\frac{1}{1-\alpha}}}{1+r-\delta}\mathbb{E}_t V^F(p_{f,t+1}, X_{f,t+1}) \\ \text{s.t. } X_{f,t+1} &= qX_{f,t}, \\ p_{f,t+1} &= p_{f,t}/\pi, \\ \mathbb{E}_t V^F(p_{f,t+1}, X_{f,t+1}) &= \phi V^F_{nadj}(p_{f,t+1}, X_{f,t+1}) + (1-\phi)V^F_{adj}(X_{f,t+1}). \end{aligned} \tag{1.24}$$

## 1.A.3 Individuals' decision-making problem

As both assets are perfect substitutes, it is useful to introduce $\widetilde{\Omega}_{i,t}$, which is individual $i$'s detrended level of real wealth at the beginning of period t.

If it is possible to adjust the nominal wage in period $t$, the worker's problem is

$$
\begin{aligned}
& V^W_{adj}(\tau_{i,t}, \widetilde{\Omega}_{i,t}) \\
= & \max_{\widetilde{C}_{i,t}, \widetilde{w}_{i,t}, \widetilde{\Omega}_{i,t+1}} \left\{ \ln(\widetilde{C}_{i,t}) - \eta \frac{H_{i,t}^{1+\kappa}}{1+\kappa} + \beta \mathbb{E}_t V^W \left( \tau_{i,t+1}, \widetilde{w}_{i,t+1}, \widetilde{\Omega}_{i,t+1} \right) \right\} \\
& \text{s.t.} \\
& \widetilde{w}_{i,t+1} = \frac{\widetilde{w}_{i,t}}{a^{\frac{1}{1-\alpha}} \pi}, \\
& \tau_{i,t+1} = \tau_{i,t} + 1, \\
& \widetilde{C}_{i,t} + a^{\frac{1}{1-\alpha}} \widetilde{\Omega}_{i,t+1} = (1 + r - \delta) \widetilde{\Omega}_{i,t} + \widetilde{w}_{i,t} H_{i,t}, \\
& \widetilde{\Omega}_{i,t+1} \geq 0, \\
& H_{i,t} = \left( G^H_{i,t} \right)^{\theta-1} \left( \frac{\widetilde{w}_{i,t}}{\widetilde{w}} \right)^{-\theta} L_t, \\
& \mathbb{E}_t V^W \left( \tau_{i,t+1}, \widetilde{w}_{i,t+1}, \widetilde{\Omega}_{i,t+1} \right) = \omega V^W_{nadj} \left( \tau_{i,t+1}, \widetilde{w}_{i,t+1}, \widetilde{\Omega}_{i,t+1} \right) \\
& \qquad\qquad + (1-\omega) V^W_{adj} \left( \tau_{i,t+1}, \widetilde{\Omega}_{i,t+1} \right).
\end{aligned}
\tag{1.25}
$$

Workers who cannot adjust their nominal wages face the following problem:

$$
\begin{aligned}
& V^W_{nadj}(\tau_{i,t}, \widetilde{w}_{i,t}, \widetilde{\Omega}_{i,t}) \\
= & \max_{\widetilde{C}_{i,t}, \widetilde{\Omega}_{i,t+1}} \left\{ \ln(\widetilde{C}_{i,t}) - \eta \frac{H_{i,t}^{1+\kappa}}{1+\kappa} + \beta \mathbb{E}_t V^W \left( \tau_{i,t+1}, \widetilde{w}_{i,t+1}, \widetilde{\Omega}_{i,t+1} \right) \right\} \\
& \text{s.t.} \\
& \widetilde{w}_{i,t+1} = \frac{\widetilde{w}_{i,t}}{a^{\frac{1}{1-\alpha}} \pi}, \\
& \tau_{i,t+1} = \tau_{i,t} + 1, \\
& \widetilde{C}_{i,t} + a^{\frac{1}{1-\alpha}} \widetilde{\Omega}_{i,t+1} = (1 + r - \delta) \widetilde{\Omega}_{i,t} + \widetilde{w}_{i,t} H_{i,t}, \\
& \Omega_{i,t+1} \geq 0, \\
& H_{i,t} = \left( G^H_{i,t} \right)^{\theta-1} \left( \frac{\widetilde{w}_{i,t}}{\widetilde{w}} \right)^{-\theta} L_t, \\
& \mathbb{E}_t V^W \left( \tau_{i,t+1}, \widetilde{w}_{i,t+1}, \widetilde{\Omega}_{i,t+1} \right) = \omega V^W_{nadj} \left( \tau_{i,t+1}, \widetilde{w}_{i,t+1}, \widetilde{\Omega}_{i,t+1} \right) \\
& \qquad\qquad + (1-\omega) V^W_{adj} \left( \tau_{i,t+1}, \widetilde{\Omega}_{i,t+1} \right).
\end{aligned}
\tag{1.26}
$$

For a worker $i$ who reaches the retirement age $TR$ in period $t$, the value function in the subsequent period is given by the value functions of retirees, i.e.

$$V^W(TR+1, \widetilde{w}_{i,t+1}, \widetilde{\Omega}_{i,t+1}) \;=\; V^R(TR+1, \widetilde{\Omega}_{i,t+1}). \tag{1.27}$$

The retirees' value function is the outcome of the optimization problem:

$$\begin{aligned} & V^R(\tau_{i,t}, \widetilde{\Omega}_{i,t}) = \max_{\widetilde{C}_{i,t}, \widetilde{\Omega}_{i,t+1}} \left\{ \ln \widetilde{C}_{i,t} + \beta V^R(\tau_{i,t+1}, \widetilde{\Omega}_{i,t+1}) \right\} \\ & \text{s.t.} \\ & \tau_{i,t+1} = \tau_{i,t} + 1, \\ & \widetilde{C}_{i,t} + a^{\frac{1}{1-\alpha}} \widetilde{\Omega}_{i,t+1} = (1 + r - \delta)\widetilde{\Omega}_{i,t}, \\ & \widetilde{\Omega}_{i,t+1} \geq 0. \end{aligned} \tag{1.28}$$

The boundary conditions of newborn households is

$$\widetilde{\Omega}_{i,t} \;=\; 0 \qquad \textit{for } \tau_{i,t} = 1.$$

The future value function of individuals in the final periods of their lives is normalized to zero. □

# 1.B Choice of Parameter $q$

As has been explained in Footnote 4, the growth rate of firm-specific productivity $q$ in our model corresponds to the ratio of the experience gross growth rate and the cohort gross growth rate in Adam and Weber (2019a). Adam and Weber (2019a) do not report estimates of this ratio explicitly. However, they calculate several possible values for optimal inflation from which values for $q$ can be inferred.

In their baseline estimation of optimal inflation rates, they find a mean of the optimal inflation rate of 1.1% (see p. 728 of their article). When wages are flexible and a sales subsidy eliminates the state-steady distortions due to monopolistic competition (as in their model), the optimal steady-state inflation rate equals $q$. Thus $q = 1.011^{1/4}$ would be in line with the value that they obtain implicitly in their baseline estimation. An alternative value for $q$ can be obtained as follows. Adam and Weber use BDS employment data to infer $q$. In particular, they compute the ratio of average employment in establishments that are not new over the average employment in all establishments. They obtain a ratio of 1.07. As mentioned on p. 727 in their paper, the employment ratio raised to the power of $1/(\varepsilon - 1)$ gives the value of $q$ (where we use the notation adopted in the present paper).[8] A low value for the elasticity of demand $\varepsilon$ that they consider is 3.8, which results in $q \approx 1.024^{1/4}$. Moreover, we have conducted an additional own analysis of BDS data that, in a way similar to Adam and Weber, identifies $q$ from employment data. This analysis that also uses more recent data leads to annual growth rates of firm-specific productivity below 1%.[9]

As mentioned in the main text, we deliberately choose a large value of $q = 1.024^{1/4}$, as large values of $q$ push the optimal inflation rate in our model upwards. In Section 1.3.6, we also examine $q = 1$ as a robustness exercise. As discussed there, the value of $q$ has only a small effect on the level of optimal trend inflation in our model (see Table 1.2).

□

# 1.C Updated Estimate of Age-dependent Productivities

As stated in the main part of the paper, we use standard values from Hansen (1993) to pin down the age-specific productivities of workers. As his analysis relies on BLS data from 1979 to 1987, we have updated his analysis to more recent data, namely the years 2013-2019.

The findings for male workers are displayed in Figure 1.13. As can be seen, our updated version leads to a hump-shaped productivity-age profile as well. Compared to the original results, the profile is steeper for younger workers, which would tend to strengthen our finding that deflation may be desirable. □

# 1.D Algorithm

In this section, we describe how we compute the steady states of our model. The different steps are the following:

[8] This relationship between the employment ratio and $q$ holds in our paper as well.

[9] The details are available upon request.

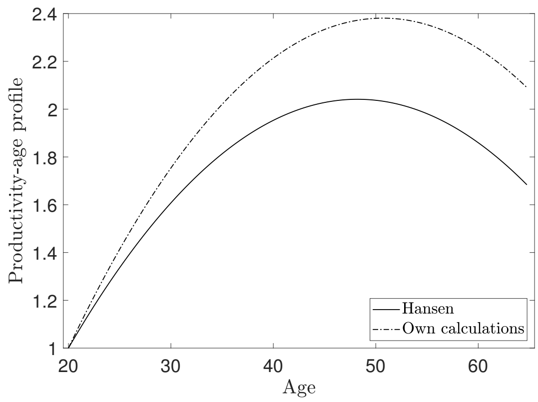



Figure 1.13: Individual labor productivity for different age groups, where the productivity of workers aged 20 years have been normalized to one. Solid line: second-order polynomial fitted to the estimates in Hansen (1993). Dash-dotted line: second-order polynomial fitted to our updated version of the estimates.

1. Fix a value of $\pi$.

2. Guess values of $r$, $\widetilde{w}$, $\widetilde{Y}$.

3. Solve firms' optimization problem via value-function iteration and simulate firm behavior to obtain the distribution of $p_{f,t}$ for all generations of firms.

4. Use the joint distribution of $X_{f,t}$ and $p_{f,t}$ to determine goods-market efficiency $A^G$ via (1.16).

5. Determine the aggregate profits of firms.

6. Determine the aggregate demand for capital $\widetilde{K}$ and labor $L$ by computing the individual demands for all intermediate-goods firms, for given prices $p_{f,t}$.

7. Use backward induction to determine the policy functions for all age groups of retirees and workers.

8. Simulate the behaviors of workers and retirees to obtain the distribution of individual wages $\widetilde{w}_{i,t}$ and capital supply $\widetilde{K}_{i,t}$.

9. Update guess on r, $\widetilde{w}$, $\widetilde{Y}$:

   - Use individual wages to determine the detrended real wage for composite labor (see equation (1.10)).

- Determine detrended aggregate output $\widetilde{Y}$ using equation (1.14). Aggregate consumption $\widetilde{C}$ is determined by aggregating individual consumption choices.
- Update r upwards or downwards, depending on whether the demand or the supply of capital are larger.

10. Compare the updated $r$, $\widetilde{Y}$ and $\widetilde{w}$ with the previous guesses. If the changes are larger than a critical value or if the difference between the demand and supply of capital is larger than a critical value, go back to 3.

□

# Chapter 2

# House Price Inflation, Low Interest Rates and Housing Choice

with Alexander Braun (University of St.Gallen)
and Julia Braun (University of St.Gallen)

## Abstract

We examine the effect of house price inflation and prolonged low interest rates on home ownership rates and the ensuing consequences for the inter-generational wealth distribution. Using survey data from the Panel Study of Income Dynamics from 1984 until 2019, we find that access to the housing market for young working generations has become more difficult in the past decades. This is true especially in areas with strong house price inflation. Based on our empirical findings, we develop a life cycle model that incorporates housing and mortgage choice.
Our model suggests that a decrease in interest rates may affect the decision to purchase a home by prolonging the savings period required for a certain down payment level. This *down payment channel* is of special importance in an environment with strong house price inflation. The *down payment channel* ultimately results in a deferral of home purchases.

This work has benefited from many valuable comments and suggestions by participants at the SFI Resarch Days 2023 at Gerzensee Institute, CEF 2023 in Nice, and by participants at the GSDS Brownbag Seminar as well as the Seminar in Macroeconomics at the University of Konstanz.

# 2.1 Introduction

While several central banks in developed economies raised their key interest rates in response to mounting inflation pressure in 2022, the impact of higher interest rates on housing decisions and, more significantly, on housing affordability, has gained considerable attention in public discussions. However, little attention has been payed to the preceding period of very low interest rates in the context of housing decisions and their implications on wealth accumulation. More specifically, the federal funds rate has reached the zero lower bound in 2008, after the financial crisis, and has basically remained at this level until 2021. Many other interest rates followed this trend.
Although the low-interest-rate environment initially appeared attractive for home buyers due to lower mortgage rates, it was also accompanied by high house price inflation. As a result, various channels of opposing forces affected individuals' housing and wealth accumulation decisions. In this work we are interested in the relationship between pronounced house price inflation, very low interest rates and the observed decline in home ownership rates among working age generations after the financial crisis.
In the context of the *secular stagnation* literature the link between the evolution of house prices and interest rates has been investigated, see e.g. Adam et al. (2022b) and Lisack et al. (2017), among others . In contrast, we take these time paths as given and focus on the implications of them on individual housing choice and wealth accumulation.

Clearly, the environment of strong house price increases and very low interest rates did not affect all generations equally in their housing decisions. Typically households in their thirties are faced with the decision of home ownership. The generation of Millennials (born between 1981 and 1996) experienced the period of interest during their thirties. Thus for their housing decision they had to take the presence of very low interest rates into account. In contrast, older generations like the Baby-boomers (born between 1946-1964), purchased their homes many years before interest rates substantially declined. The phase of low interest rates affected these generations more in their choice to sell their homes, given that the value of their homes increased strongly during this period.

We observe that home ownership rates have been declining for households in the work-

ing age during the 2010s. By postponing the purchase of a home, younger generations could not take advantage of the recent increase in housing prices. As a result, they have built up considerably less wealth compared to Baby-boomers at the same age. This finding is supported by Federal Reserve statistics, which show that the share of U.S. national wealth owned by Millennials was only 5.6% in 2021, compared to the share of 21.2% owned by Baby-boomers in 1989 when they were roughly the same age as Millennials in 2021.[1]
Using survey data from the Panel Study of Income Dynamics (PSID) from 1984 until 2019, we estimate the impact of house price inflation and the recent phase of prolonged low interest rates on housing choices across different generations. Our analysis shows that the probabilities to be or to become homeowners are significantly lower for younger generations than for the Baby boomers. Especially in U.S. states with high house price inflation the chance to purchase a home is reduced. The effect of interest rates is significant an positive, implying that the probability to own a home are higher in periods of high interest rates.

In a theoretical partial equilibrium life cycle model with housing choice and mortgage debt we investigate the effect of very low interest rates on housing choices in a context house price inflation.
Both an unexpected increase in house prices and an unexpected decline in the savings rate affect the feasibility and the duration of savings accumulation for the down payment of a home purchase. While the effect of house price inflation is clear (increased home value leads to larger down payment volume and thus longer saving period), a decline in the real interest rate has opposing effects on the housing and mortgage decision: On the one hand, lower mortgage rates make debt more attractive, leading to higher mortgage volumes and higher home ownership ceteris paribus. This mechanism is an intra-temporal substitution effect. On the other hand, lower returns to savings slow down wealth accumulation and lead to a deferral of home purchases - an income effect, which we define as the *down payment channel*. The *down payment channel* gains importance if the down payment volume is large and thus house price inflation has been strong.

Empirically and theoretically, we find that the net result of a decline in returns to savings depends on the degree of house price inflation. While under moderate house price inflation in our model of around 20% within a period of 5 years the intra-temporal sub-

[1]https://www.federalreserve.gov/releases/z1/dataviz/dfa/

stitution effect dominates, which results in higher home ownership rates among young individuals, for a stronger increase in home values of 35% the income effect of the *down payment channel* outweighs. In this case we observe a decline in home purchases among young workers.
Several other factors, such as subdued wage growth and labor market volatility after the financial crisis as well as increased student debt (see e.g. Webber and Burns (2021)), could play a vital role in explaining this wealth accumulation difference among different generations. However, we argue that also the *new normal* environment, with zero-interest rates on saving accounts accompanied by elevated prices for financial assets, may have significantly affected the households' financial market participation, especially for younger households.
Our results have important socio-economic implications. In light of longevity and a continuing change in the demographic structure of western economies, the financial burden laid on young working generation is increasing. Young individuals should accumulate more wealth than previous generations over their life cycle in order to provide enough private retirement pensions. The development towards low-risk savings behavior in combination with low key interest rates and harder access to housing markets leads to the opposite. Currently young working generations can accumulate less wealth and if they remain renters, they will have a higher exposure to the risk of increased rental prices when they are old compared to homeowners who can live in their homes until late ages.

The remainder of this paper is organized as follows. In the next section we present the literature that is related to our work. Section 2.3 contains our empirical findings, including stylized facts obtained by the PSID data related to housing choices and results from logit regressions. In Section 2.4, we introduce a life cycle model with housing choice. We test the mechanisms resulting from unexpected increases in house prices and declining interest rates in Section 2.5. Section 2.6 concludes.

## 2.2 Related literature

Our work primarily contributes to the rapidly expanding literature on the impact of macroeconomic conditions on individual housing choice and wealth accumulation. These conditions can be related to business cycles, financial asset performances or labor market volatility (see Fischer and Stamos (2013); Adam and Tzamourani (2016);

Zhou (2020); Paz-Pardo (2024)).
Adam and Tzamourani (2016) analyze how capital gains, resulting from expansionary monetary policy conducted by the European Central Bank were distributed among households. They show that only a small fraction of the population could benefit from equity and bond market gains, whereas the benefits from housing market were more equally distributed. Regarding inter-generational wealth redistribution from housing gains, we find that old-aged homeowners could benefit substantially more from house price inflation than younger generations. Zhou (2020) finds that the financial crisis has contributed to a decline in stock market participation in the U.S. Paz-Pardo (2024) links increased labor income uncertainty in the U.S. over the past decade to the reduced housing market participation of young individuals. We include his argument in our empirical analysis to identify the effect of declining interest rates in the presence of increasing labor income volatility.

A work that is closely related to ours concerning the empirical approach is by Fischer and Stamos (2013), who show that home ownership rates co-move with the housing market cycle. They find that during phases of house price booms households spend more on their homes relative to their income, which leads to increased leverage ratios compared to bust periods. Our paper differs from theirs in at least three aspects. First, while we use the same data source, the PSID data, we look at a much longer data period, which includes the after-financial crises period of low interest rates. Second, we explicitly focus on the inter-generational differences in the effects of house price variation. Third, we are interested in implications of low interest rate on housing decisions.
Other papers investigate channels through which monetary policy shocks affect housing decisions (see Wong (2019); Kinnerud (2022); Eichenbaum et al. (2022)). Eichenbaum et al. (2022) find that consumption responses to monetary policy shocks become weaker if many homeowners have just refinanced their mortgage recently. Kinnerud (2022) uses a life cycle model with housing to assess the aggregate demand responses to a monetary policy shock through an adjusted housing choice. While all of these papers take into account the individual housing and mortgage choices of different generations, they focus on short term variation in the real interest rate.

Our theoretical model is similar to the one by Wong (2019), who investigates the transmission of a monetary policy shock through refinancing of mortgages. Wong uses a general equilibrium model with housing choice and the option to refinance fixed rate mortgages. As a transitory negative interest rate shock hits the model economy, a large fraction of the consumption response is due to refinancing of mortgages among young individuals. In this framework, the mortgage volume of homeowners plays a key role for the transmission of the monetary policy shock.[2] We are interested in the impact of long-term trends in interest rates on housing choices and savings for down payments. As a period in our model is five years and a interest rate drop is permanent, we assume that all households refinance their mortgage. In line with Wong, our work shows that interest rate variation plays an important role for mortgage choices and home ownership.

Given the implications of house prices and housing choices on wealth accumulation, this paper also speaks to the strand of literature on housing choice in the context of life cycle wealth accumulation and the resulting redistributive effects.
Kuhn et al. (2020) consider historical long run data from the Survey of Consumer Finances and show that the weight of housing in asset portfolios of low and medium wealth households has increased steadily since post war. The authors argue that this evolution has contributed to a decline in wealth inequality, since the increase in house values was stronger than the increase in assets such as stocks and business equity, which are typically held to a larger extent by households at the top of the wealth distribution. Bartscher et al. (2020) show that U.S. mortgage balances, especially of young households, have been blown up in line with the increase in home values, resulting in an increased individual risk exposure of households.
While the two papers mentioned illustrate the importance of home ownership and house prices for the wealth distribution, our inequality dimension of interest is age. Regarding inter-generational wealth redistribution due to housing gains, we find that old-aged homeowners could benefit substantially more from house price inflation than younger generations.
Arundel (2017) investigates the impact of home ownership on the increase in inter- and intra-generational inequality in the UK from a sociological perspective. As opposed to our work, Arundel (2017) does not take into account the role of low interest rates on individual housing decisions.
Another strand of the literature, e.g. Xu et al. (2023) and Barczyk et al. (2023), examines the savings and housing decisions of elderly individuals in the presence of longevity and elderly care. We abstract from implicit inter-generational contracts among rela-

[2] Wong (2019) finds that the consumption response to the interest rate shock declines in age. This is because mortgages are repayed over the life cycle and, thus, mortgage volumes decline in age reducing the incentive to refinance mortgages in the presence of fix costs for adjustment.

tives to identify the effects of house price inflation and low interest rate periods through a savings channel only.

## 2.3 Empirical analysis

In this section, we present stylized facts on the evolution of economic household characteristics related to housing decisions, and we conduct an analysis to identify the statistical effects of increased home values and low interest rates on home ownership decisions.

### 2.3.1 Data

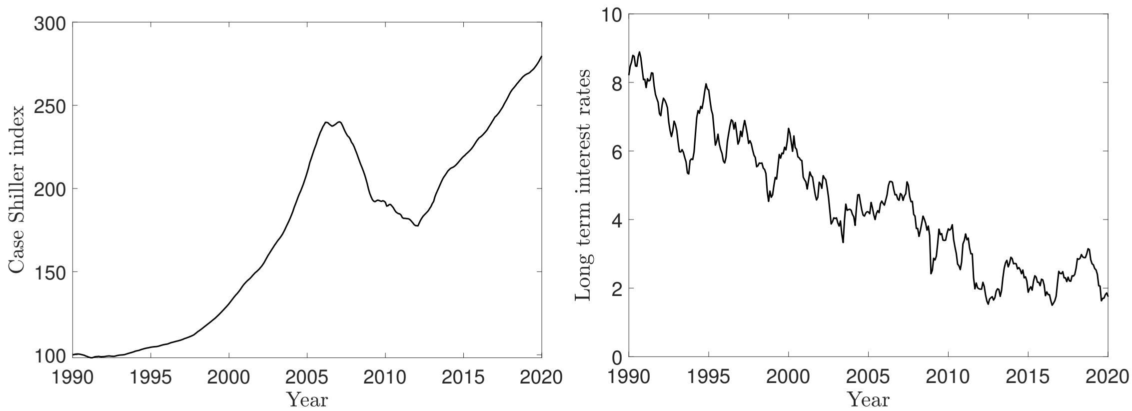
We use data from the Panel Study of Income Dynamics (PSID), which is a large representative U.S. longitudinal household survey. The PSID provides detailed information on individuals' demographics, income, and wealth, which are relevant for our analysis. Compared to other frequently used data sources, such as the Survey of Consumer Finances, the PSID is designed such that individuals can be tracked over different waves. This feature is central to our analysis, as it enables us to study households that purchase a house for the first time. By knowing the economic history of these households, we can gain insights into the circumstances under which housing decisions are made.
For our analysis we use data covering the years 1984 until 2019. Questions regarding respondents' wealth status have first been asked in a wealth supplement starting in 1984 on a five year frequency. The wealth supplement has been added to the core survey in 1999. This is why from 1999 on, data on wealth exist on a biannual frequency. For prior periods we have information on wealth for the years 1984, 1989 and 1994.
We only use the representative Survey Research Center (SRC) sample, which is representative for the U.S. population and therefore does not require population weights.[3] Following Fischer and Stamos (2013), we drop all observations with missing information on our control variables, such as age of household head, house value, net worth without home equity, or taxable income.
In order to make sure that all age groups are represented by enough respondents, we only consider households aged 20 to 85. Moreover, we exclude households born before 1945 and after 1996. These cohorts are relevant for our period of interest, since they

[3] These include households with the family identification number up to *2930*.

belong to the age groups 20 to 85 at some point in time between 1984 and 2019. Furthermore, the birth years considered can be assigned to three generations, which are the Baby-boomers (born between 1945 and 1964), generation X (born between 1965 and 1980) and the Millennials (born between 1981 and 1996). For each year considered we are left with data on approximately 2000-3500 households.

### 2.3.2 Interest rates, house prices and asset choices

The evolution of the *S&P* Case-Shiller U.S. National Home Price index and 10 year government bond yields from 1999 until 2019 are depicted in Figure 2.1. The Case-Shiller index represents the evolution of U.S. house prices and is normalized to 100 in 1999. To illustrate the path of interest rates, we use an 10 year government bond yields, as they are of comparably low risk and of a long duration. Thus they correlate strongly with other interest rates and can be considered a proxy for the pattern of both, mortgage rates, which are typically of long duration, and returns to assets containing little risk.



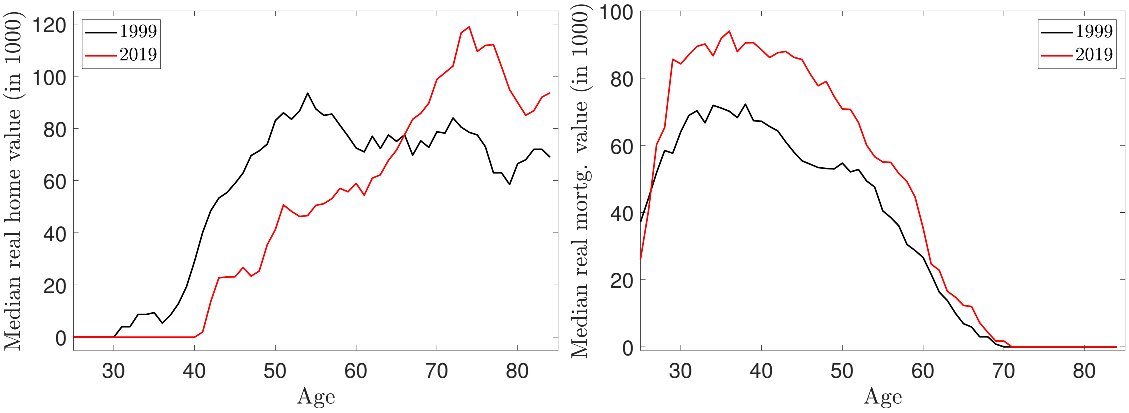

(a) Case-Shiller Index, normalized to 100 in Jan. 1990

(b) 10 year U.S. government bond yields

Figure 2.1: The evolution of house prices and interest rates

For the government bond yield a clear downward trend can be observed, which reaches a persistently low level of around 2% after 2010. This period coincides with the federal funds rate reaching a level close to the zero lower bound.
The Case-Shiller index has been increasing by around 60% in the 2000s, and it has recovered quickly after the collapse related to the financial crisis. Thus for the years after the financial crisis until 2019 we observe that interest rates have persisted at a

very low level, while house prices increased substantially. Both variables are important for individuals' decisions to purchase a home.




(a) Median real house values

(b) Median real mortg. values of home owners

Figure 2.2: House values and mortgage volumes across age groups over time, adjusted by inflation with 1999 as a baseline year.

The effects of increased home prices and lower interest rates on mortgage volume and home values are depicted in Figure 2.2. The right of Figure 2.2 reflects the median mortgage sizes of home owners across age groups for four different years between 2019 and 1999. Mortgage values are adjusted to CPI inflation with 1999 as a baseline year. Median mortgage values increasedfor most age groups. This indicates that households could not finance increased home values with equity only and became indebted more strongly.[4] However, as mortgage rates declined during the period of time considered, debt holdings became more affordable.

Especially young individuals hold substantially larger mortgage volumes in 2019 compared to 1999. Median house values, depicted in the left graph of the second row, show the opposite life cycle pattern. Again, we consider inflation adjusted home values. Note that in this graph we do not condition on home ownership. Among young households median home values have remained at zero until later ages in 2019 compared to 1999, implying that home ownership rates have been below 50% for these cohorts. Among middle-aged cohorts, median real home values in 2019 are below the levels of 1999, indicating that these generations purchase smaller homes. While for elderly households above the age of 65 in 1999 home values decline slightly, in 2019 they keep increasing.

[4]Figure 2.11 in the Appendix shows that house value to income ratios of home owners increased since 2000. This implies that nominal wage increases were lower than house price inflation and therefore many households finance their home by a larger extent with debt recently.

This observation indicates that retirees tend not to downsize their homes any more and that the home value gain from house price inflation has been increasing in age.

So far we have seen that house prices increased strongly, which contributed to higher mortgage volumes among all generations and lower home ownership rates among the young. Given that interest rates have been at a low level in the 2010s, the question arises, which assets households choose for their savings. As we illustrate in Appendix 2.A.1, many households did not invest their wealth into assets bearing high interest. This observation is surprising, as one would expect that households save in terms of more risky assets, if the return to safe assets is extremely low (see Lian et al., 2019). Instead, the fraction of households storing their wealth on their checking accounts or on government bonds only has increased. We call these agents *liquid savers*. They receive almost no return to their savings if the key interest rate is low.
Given the strong performance of stock market compared to low-risk assets (see Figure 2.12 in the Appendix), it is surprising that an increasing share of households stores its value in terms of *liquid assets*. This result, however, is in line with Zhou (2020), who shows that stock market in the U.S. participation has declined after the financial crisis. We use this fining in our later analysis, where we investigate the effect of low interest rates on down payment savings for home purchases, the *down payment channel*.

According to Fischer and Stamos (2013), the booming housing market of the last decade should attract potential home buyers. Figure 2.3 suggests that this does not hold for all age groups in a long-run consideration. The graph reports home ownership rates, split into working-age households (20-64 years old), and retirees (65 years and older) from 1984 until 2019. A household's age refers to the head's age. While home ownership rates increased until the early 2000s for both age groups, the patterns diverge after the financial crisis. In the aftermath of the financial crisis, the fraction of working-age homeowners has steadily declined. The housing market participation rate of the elderly cohort, in contrast, has increased over the decades. This pattern is in line with 2.2. We suspect that both trends in home ownership rates are related to the increased house price inflation. Young households cannot afford a home any more, if homes are too expensive. Furthermore, stricter regulations in down payment requirements and bank loans after the financial crisis might have contributed to the decline in home ownership rates among younger cohorts. In contrast, the elderly keep their home, as it is a valuable asset. Longevity might decrease the incentive to sell the owned home further, see Barczyk et al. (2023).

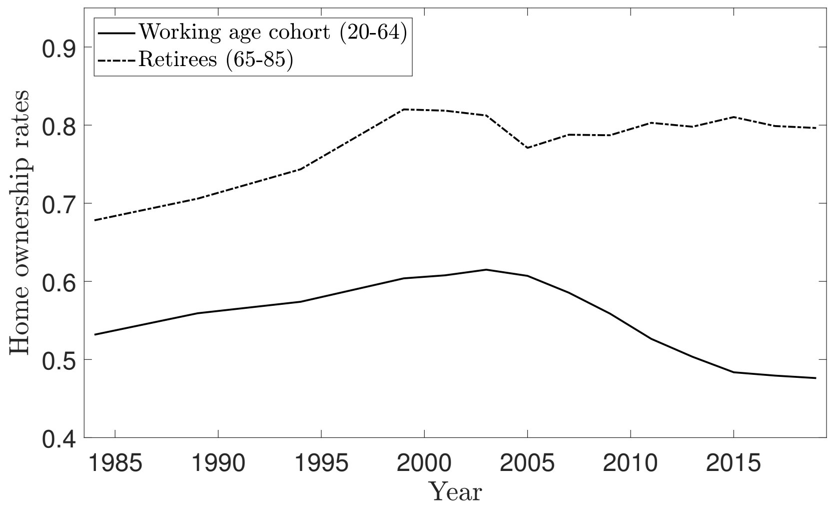



Figure 2.3: Home ownership rates by age cohorts

How did the strong performance of housing market affect life cycle wealth accumulation and inter-generational wealth inequality over the past decades? Kuhn et al. (2020) show that for the bottom 90% of U.S. households housing makes a large fraction of their financial assets. The evolution of house prices over an individual's life cycle as well as the decision to purchase a home have been decisive for the evolution of individual wealth holdings over the past decades.

Figure 2.4 shows the median net wealth holdings with (solid lines) and without (dashed lines) home equity for 1999 (black) and 2019 (red). In order to make the years comparable, the level of wealth holdings are inflation adjusted with the base year of 1999. Focusing on wealth including home equity first, we make two main observations. First, wealth holdings of retirees have increased within 10 years. Second, median wealth holdings of the working have declined. These observations lead to a shift in wealth holdings including home equity towards older generations.

Median wealth holdings excluding home equity show a similar pattern qualitatively, but not as pronounced. It is worth mentioning that for households aged 20-40 wealth without home equity persists at a very low level and only increases slightly for older age groups in 2019. This suggests that savings accumulation has slowed down in 2019 compared to 1999, which makes access to housing more difficult, if a down payment is required for home purchase.[5]

Comparing the difference between wealth with and without equity in a given year, we

[5]We check the evolution of gifts or bequests received in the PSID data. We don't find a substantial increase in large asset transfers to young households over time, which could make a down payment affordable without long periods of savings accumulation.

can observe that in 2019 home equity makes an even larger share of households' wealth than in 1999. Thus housing as an asset has been gaining importance in individual portfolios.

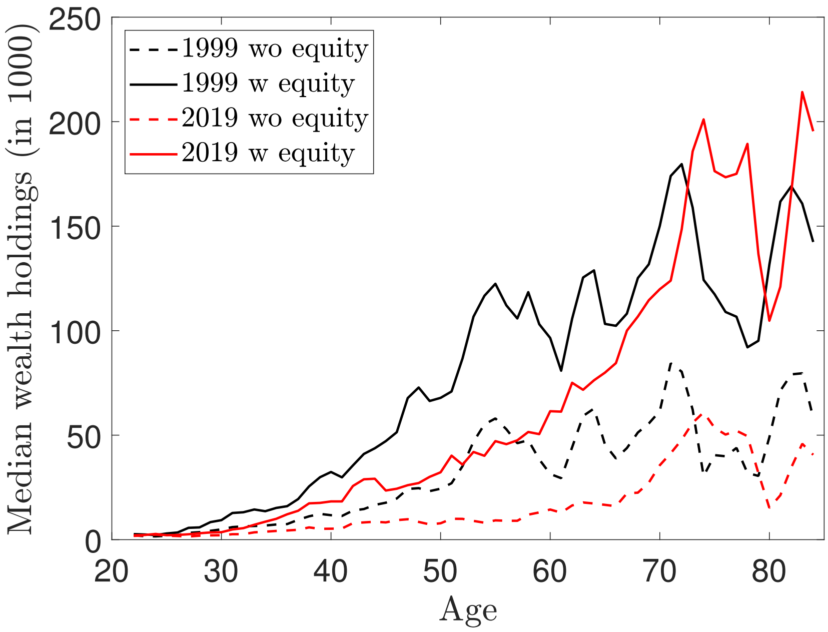



Figure 2.4: Median real wealth holdings with and without home equity: 1999 vs 2019

### 2.3.3 Logit regressions on home ownership

In this section, we statistically test the importance of socio-economic household characteristics and financial environment factors for individual home ownership status. For this purpose, we employ a set of control variables to examine the likelihood of being a homeowner and becoming a homeowner for the first time. We do so by running logit regressions on the individual status of home ownership. We use PSID data from 1984 to 2019. During this period, substantial variation in interest rates and house prices can be observed. In our analysis we distinguish between two dependent variables. The first dependent variable captures the current status of home ownership, while the second variable reflects a transition from being renter to becoming homeowner.

We are particularly interested in the observation that young households postpone their home purchase. Hence the second specification of our dependent variable is of special interest. However, this requires tracking households over time to determine the timing of the status change. More specifically, we consider households that become homeowners for the first time. We define new homeowners as households heads who change status from being *renter* to *homeowners*, who haven't owned a house before and who stay homeowner for at least two more waves. We impose the latter restriction in order to avoid reporting errors. The sample for the second analysis is restricted to those households that can be tracked from 1984 to 2019 with no missing values for the entire sample.

Following Fischer and Stamos (2013) and Zhou (2020), we control for well established household characteristics, such as age, race, college degree and several others. In addition to these variables, we are particularly interested whether the likelihood to be a homeowner depends on the generation of the household. Based on our descriptive analysis, we expect subsequent generations of the Baby-boomers (born between 1946 and 1964) to face a lower chance to become homeowner than the Baby-boomer cohort. We therefore add control dummies for observed households belonging to generation X, born between 1965 and 1980, or to the Millennials, born between 1981-1996.
Besides socio-economic factors, the economic and financial environment might affect individual housing decisions. For both dependent variables we test whether there is a statistically significant relationship between individual home ownership and the level of interest rates. We use a 15-year mortgage rate in our analysis. However, the choice of alternative interest rates (10-year government bond yields, 30-year mortgage rates), do not change our results significantly.

We control for income volatility, where we use the observed standard deviation of household income per year. Moreover, we account for the potential changes in preferences for home ownership, e.g. due to increased spatial mobility. We approximate a mobility variable by computing the share of households that moved since last spring prior to the survey wave.[6]

We provide the summary statistics in Table 2.1 for our sample from 1984 to 2019, where we distinguish observed households by their home ownership status. The numbers are given by sample means or shares, if referred to generations. The statistics for age, race, gender and education refer to the household heads. The other variables are reported at the household level. Table 2.1 reveals that homeowners and non-homeowners differ with respect to several factors. Among homeowners a considerably higher share of households belongs to the group of entrepreneurs, has a college degree and received an inheritance in the past. Noteworthy, homeowners own almost threefold of non-housing wealth compared to non-homeowners. Regarding the age composition among the two

[6]The mobility variable increases from 1990 to 2005 and declines after the financial crisis.

groups, we find that almost two thirds of the homeowners belong to the Baby-boomer generation, while non-homeowners are roughly equally distributed across generations among the pooled sample. This is also reflected in the higher average age of homeowners than non-home owners.

| **Summary Statistics, Household Level** | | |
|---|---|---|
| | Homeowners | Not homeowners |
| Age of head | 45.7 | 39.8 |
| Baby-boomers (1946-1964) | 0.633 | 0.347 |
| Generation X (1965-1980) | 0.289 | 0.369 |
| Millennials (1981-1996) | 0.077 | 0.284 |
| Received inheritance/gift | 0.080 | 0.039 |
| Race: white | 0.916 | 0.762 |
| Education: college | 0.439 | 0.269 |
| Entrepreneur | 0.148 | 0.065 |
| No. of children in the family | 0.914 | 0.873 |
| Non-housing wealth | 350'525 | 118'960 |

Table 2.1: Summary Statistics

The table reports the mean characteristics or the share for the categorical variables of observed households aged between 20 and 85. Column 1 refers to homeowners and column 2 to non-home owners.

As a next step, we estimate two multivariate logit regression models for the likelihood of being a homeowner and for the likelihood of becoming a homeowner.

Following Fischer and Stamos (2013), we estimate a pooled multivariate logit model of home ownership using PSID data from 1984 to 2019. We study which factors contribute the probability of being and becoming homeowner. Since we are particularly interested in the observation that young households postpone their house purchase, we focus on the households, who have become homeowner for the first time.

Our control variables include various demographic and social explanatory variables (race, education, the number of children under age 18, financial wealth without housing, private business ownership) as well as macroeconomic and macro-financial variables, such as the Case-Shiller return, real 15 year mortgage rates, income volatility, and the Chicago Board Options Exchange Volatility Index (VIX), which measures the expected volatility of the U.S. stock market.
As noted earlier, preferences for home ownership and spatial mobility may have changed over time, which is likely to have an impact on housing decisions. We account for this by including the share of households moved in the previous year as a control variable. Our core variable of interest is the national interest rate level, which we measure using

the 15-year mortgage rates.

To capture the generational effects on the outcome variable, we include two dummy variables for households belonging generation X or to the Millennials The coefficients for these dummy variables reflect the probabilities of these generations to be or to become home owner relative to the reference generation of the Baby boomers.

| **Homeownership, Logit Regressions** | | |
|---|---|---|
| Dependent Variable: | Be homeowner | Become homeowner |
| **Generation controls** | | |
| Generation x (1965-1980) | $-0.065$ | $-0.843^{***}$ |
| Millennials (1981-1996) | $-0.288^{***}$ | $-1.116^{***}$ |
| **Macro-financial controls** | | |
| Case-shiller return | $0.019^{***}$ | $0.098^{***}$ |
| Real 15-year mortgage rate | $0.046^{***}$ | $0.249^{***}$ |
| Vix index | $0.008^{**}$ | $-0.007^{***}$ |
| **Household controls** | | |
| Received inheritance/gift | $0.481^{***}$ | $1.104^{***}$ |
| Race: white | $1.18^{***}$ | 0.042 |
| Education: college | $0.648^{***}$ | $0.521^{***}$ |
| Entrepreneur | $0.754^{***}$ | 0.198 |
| No. of children in the family | $0.375^{***}$ | 0.115 |
| Log non-housing wealth | $-0.004$ | $-0.011$ |
| Share of households moved last year | $0.188^{***}$ | $-0.462$ |
| Income volatility | $-0.004^{***}$ | $-0.018^{***}$ |
| Constant | $-6.23^{***}$ | $17.469^{***}$ |
| No. of observations | 30,968 | 2,248 |

Table 2.2: Homeownership Logit Regression

The fist column reports the results of logit regression that examines whether real 15-year mortgage rates and household-specific control variables have significant impact on individual household home-ownership status for households aged between 20 and 85. The second column reports the results for the households, which became homeowner for the first time and stayed in this status at least for two years, so that the status stays unchanged in the next wave. We exclude households born before 1945 and after 1996 in order to focus on the generations of Baby-boomers (born between 1946-1964), Generation x (1965-1980) and the Millennials (1981-1996). Following Fischer and Stamos (2013), we exclude all households years with missing observations control variables we use throughout our empirical analysis. $^{***}$, $^{**}$ and $^{*}$ indicate significance at the one, five, and ten percent levels, respectively.

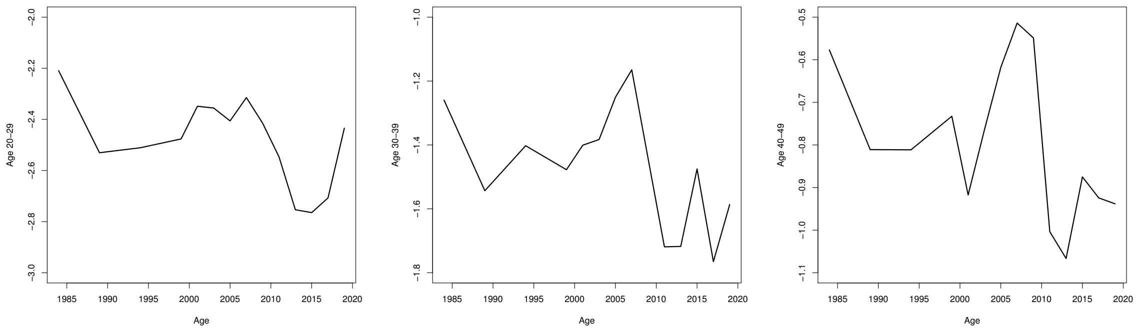
The results for the logit regressions on the two dependent variables *be homeowner* and *become homeowner* are presented in Table 2.2. First, individual characteristics like having a college degree, being an entrepreneur, having received an inheritance or being of white race have a positive significant impact on the probability of being a

homeowner. An inheritance as well as a college degree also significantly increase the probability of becoming homeowner.
Unsurprisingly, income volatility has a negative impact on both dependent variables. In line with Fischer and Stamos (2013), we find that Case-Shiller returns are positively related to being and becoming homeowner. The result indicates that home ownership rates should have risen during years of strong house price inflation. However, Figure 2.3 shows the opposite pattern for young individuals. To have better insights in the effects of home value increases, we do a more detailed analysis in the next section.
Importantly, we document that interest rate level have a statistically significant positive impact on the home ownership status. This implies that the probabilities to be and to become homeowner deteriorate, if interest rates decline.

Regarding the probability for different generations to participate in the housing market, the Millennials face a significantly lower probability to be and to become homeowners than the Baby-boomers. Also for generation X the chance to become homeowner is lower than for Baby-boomers.
This result might arise, because in our pooled sample Baby-boomers are always older than the other generations. As home ownership increases over age, the effects related to generations might actually be related to age.

An alternative method to test our hypothesis that home ownership rates among young generations has been declining is to conduct a regression analysis using age-cohorts instead of generation dummies. As a base-category, we define households aged 50 and older. This approach yields coefficients for age group dummies 20-29, 30-39 and 40-49. For each year we run a logit regression such that we can observe how the regression coefficients for the age groups considered evolve over time.

The results displayed in Figure 2.5 show a clear drop in the probability of the three age groups to become homeowners relative to the baseline group of household heads aged 50 and older. This implies that in the 2010s the access to home ownership among the working age generation has become harder - despite persistently low interest rates during this time period.




(a) $\beta_{20-29}$ (b) $\beta_{30-39}$ (c) $\beta_{40-49}$

Figure 2.5: Age-cohorts regression coefficients per year

The three charts in this figure display the regression coefficient for the corresponding age-cohort dummy variable over time. These coefficients were obtained from individual year regressions and represent the estimated effect of each age-cohort on the outcome variable while controlling for other relevant factors.

### 2.3.4 Effects of strong house price inflation on home ownership

In order to better understand why younger cohorts' home ownership rates declined despite low mortgage rates and opportunities of value gains on the housing market, we take a closer look at the effect of house price inflation. We suspect that home ownership rates increase in home prices, as long as households can still afford the home purchase and the required down payment.

For our next analysis we distinguish between states that grew by less and by more than 50% in their house prices between 2011 and 2019. We conduct a difference-in-difference analysis to explore the effect of very high price inflation to home ownership.

For this purpose we use data from the Zillow Home Value Index instead of the Case-Shiller index. The Zillow index provides detailed information on the evolution of house prices on U.S. state level. The percentage changes in house prices on the state level are displayed in Appendix 2.B.

In our analysis 16 states are part of the treatment group, which experienced more than 50% house price inflation in time period considered.

The results of the difference-in-difference logit regressions are shown in Table 2.3. For both dependent variables, *be homeowner* and *become homeowner*, the treatment effect is negative, implying that in high house price inflation states the probability of home

| | Be Homeowner | Become Homeowner |
|---|---|---|
| Treatment High Price States | -0.345*** | -0.326** |
| (High Price Growth States, 2011-2019) | (0.012) | (0.008) |
| Treatment Young Adults 20-45 in High Price States | -0.348*** | -0.327** |
| (High Price Growth States, 2011-2019 Young Adults 20-45) | (0.069) | (0.139) |
| Household Controls | Yes | Yes |
| **Fixed effects** | | |
| Year FE | Yes | Yes |
| Houeshold FE | Yes | Yes |

Table 2.3: Difference-in-Difference Logit Regression

This table reports the difference-in-difference regression estimates for the relationship between high price growth states and the status of being an homeowner and becoming homeowner. High price growth states are defined as a growth rate of more than 50 percent from 2011-2019, based on the Zillow Home Value Index (ZHVI), which measures the typical value for homes in the 35th to 65th percentile within a state (California, Florida, New York, Georgia, North Carolina, New Jersey, Washington, Massachusetts, Maryland, Wisconsin, Colorado, Louisiana, Oregon, Connecticut, Nevada, New Mexico, Idaho, Hawaii, Rhode Island, North Dakota, Alaska,District of Columbia).

ownership is lower than in other states. We also find a negative and significant impact on young households aged 20 to 45 in states with strong house price increases. Thus younger cohorts are affected more negatively in their probability to be and to become home owner than older generations, in states of strong house price inflation.

Our results show that the degree of house price inflation matters for households in their access to home ownership. In the next section we introduce a life cycle model with housing choice to show that a decline in interest rates in combination with a strong increase in house prices can lead to a reduction in home ownership rates among young households and to a deferral in house purchases.

### 2.3.5 Implications on wealth accumulation

In the next step, we aim to investigate the relationship between home ownership status and wealth. To accomplish this, we separate the observed households into total net wealth quartiles and deciles in each year. We test whether homeowners are more likely to belong to the top 25% or to the top 10% of wealth distribution.

In addition, we are interested in the determinants of being a *liquid saver*. As described earlier, we define these saver types as households who hold their total wealth in terms of relatively liquid assets with low risk exposure and low returns. In our liquid saver analysis we are interested in the impact of interest rates and house prices on the dependent variable.

| **Logit regressions wealth and saving behaviour** | | | |
|---|---|---|---|
| | Top 25% of wealth d | Top 10% of wealth d.. | Liquid saver |
| Home ownership | 1.679*** | 1.409*** | |
| Age of head | 0.081*** | 0.051*** | −0.084*** |
| Age of head$^2$/100 | −0.042** | −0.009*** | 0.046*** |
| Generation X (1965-1980) | −0.699*** | −0.762*** | 0.439*** |
| Millennials (1981-1996) | −0.867*** | −1.031*** | 0.630*** |
| Received inheritance/gift | 0.828*** | 0.784*** | −0.575*** |
| Race: white | 1.277*** | 1.329*** | −0.168*** |
| Education: college | 1.128*** | 1.120*** | −0.401*** |
| Entrepreneur | 1.783*** | 1.828*** | −0.741*** |
| No. of members in the family | 0.029** | 0.053** | −0.291*** |
| ln(non-housing wealth) | 0.002 | 0.003 | −0.038 |
| Case-Shiller return | | | 0.019*** |
| Vix index | | | 0.055*** |
| Share of households moved last year | | | 2.255*** |
| income variance | | | 0.003* |
| Real 15-year mortgage rate | | | −0.111*** |
| Constant | −7.156*** | −7.879*** | −0.381 |
| No. of observations | 30,968 | 30,968 | 29,810 |

Table 2.4: Logit regressions on wealth and saving behavior

The first and second column report the results of logit regression on the probabilities to belong to the top quartile or top decile of the wealth distribution. The third column shows the regression results on the probability to be a *liquid saver*, i.e. to save in terms of assets with low yields and a high degree of liquidity only. ***, ** and * indicate significance at the one, five, and ten percent levels, respectively.

Our analysis reveals that homeowners as well as individuals belonging to the Baby-boomer generation are more likely to be among the wealthiest 25% and 10% of the population, respectively.

Conversely, lower interest rates are linked to a higher probability of belonging to the group of savers who hold low-yielding assets, such as checking accounts and government bonds. Thus the regression confirms that during periods of lower inflation a larger share of households store their wealth in terms of assets with very low return.

The definition of a liquid saver excludes the possibility, that liquid saver types can be homeowners. Given that homeowners are more likely to belong to the richest households and liquid savers cannot accumulate wealth rapidly trough their returns to savings, our results suggest an increase in wealth inequality among homeowners and non-homeowners.

# 2.4 Model

We use a partial equilibrium model with housing choice and mortgage debt to further investigate the mechanism behind the relationship of house price inflation, interest rates and home ownership rates.
We conjecture that a minimum down payment requirement might explain why individuals defer their home purchase in periods of low interest rates and high house prices: A persistent decline in interest rates leads to a negative income effect for savers, which implies that individuals have to save for a longer time horizon in order to be able to meet the down payment requirement. We call this negative income effect on home ownership the *down payment channel*.
However a second channel of opposing force arises that affects the choice on home ownership. In our model a decline in the savings rate leads to a lower mortgage rate, which makes mortgage debt more attractive. The intra-temporal substitution effect results in increased home ownership.
Which of the two effects related to a decline in interest rates dominates depends on the size of house price inflation. If house prices grow at low rates, the intra-temporal substitution effect may dominate and lead to higher home ownership across generations. Under strongly increasing house prices, the *down payment channel* may dominate.

## 2.4.1 Model description

In each period t the economy is populated by many individual households i. The households work for T periods and retire thereafter for TR periods. Households face a death probability $d(\tau_{i,t}) \in [0, 1]$, depending on age $\tau_{i,t}$. After having reached age $T + TR$, the households die with certainty.
Households derive utility from consumption $c_{i,t}$ and housing services $s_{i,t}$. Households can decide to purchase or rent one unit of housing in each period. The utility function is given by

$$u(c_{i,t}, s_{i,t}) = \frac{\left(c_{i,t}^{\epsilon}\mathbb{1}_{\chi}(h_{i,t+1})s_{i,t}^{1-\epsilon}\right)^{1-\sigma}}{1-\sigma}$$
$$\mathbb{1}_{\chi}(h_{i,t+1}) = \begin{cases} \chi, & if\ h_{i,t+1} > 0 \\ 1, & if\ h_{i,t+1} = 0. \end{cases}$$

where $\epsilon$ measures the intra-temporal elasticity of substitution between consumption and housing services, and $\sigma$ is the inter-temporal elasticity of substitution. The indicator function $\mathbb{1}_{\chi}(h_{i,t+1})$ becomes $\chi > 1$, if the household owns or purchases a home during the given period, i.e., $h_{i,t+1} > 0$, and 1 otherwise. We follow Paz-Pardo (2024) by assuming that leaving bequests upon death yields utility to the household according to

$$v(w_{i,t}) = \frac{B_2\left(B_1 w_{i,t}\right)^{1-\sigma}}{1-\sigma},$$

where $w_{i,t}$ is the level of wealth, which is passed on, consisting of assets and home equity. $B_1$ and $B_2$ are positive bequest parameters.

## Labor income process

Workers inelastically supply labor and they receive a stochastic labor income $y_{i,t}$ each period, which evolves according to

$$\begin{aligned} log(y_{i,t}) =& \omega(\tau_{i,t}) + \eta_{i,t} \\ \eta_{i,t} =& \rho\eta_{i,t-1} + \psi_{i,t} \\ \psi_{i,t} \sim& N(0, \sigma_{\eta}^2) \\ \sigma_{\eta}^2 >& 0 \\ \rho \in& (0, 1), \end{aligned}$$

where $\omega(\tau_{i,t})$ denotes the deterministic and age dependent component of labor income and $\eta_{i,t}$ is the stochastic component (see Wong, 2019). Retired households receive social security transfers, as modeled by Guvenen and Smith (2014) (see also Wong (2019)).

## Assets

Household i can save in terms a liquid risk-free asset $a_{i,t}$. Furthermore, individual i can hold housing assets of quality $h_{i,t}$ at price $p_t$ per housing unit. The available set of housing qualities is discrete. In every period, household i holds $a_{i,t}$ and $h_{i,t}$ as state variables and chooses $a_{i,t+1}$ and $h_{i,t+}$. The liquid asset $a_{i,t} > 0$ yields a risk-free return $r_t$.

In order to purchase a house of quality $h_{i,t+1}$ at price $p_t$ per housing unit, the household can apply for a mortgage $m_{i,t+1}$. The collateral constraint is

$$m_{i,t+1} \leq \lambda p_t h_{i,t+1},$$

where $\lambda \in [0,1]$ represents a minimum down payment rate and $m_{i,t+1} \geq 0$. The mortgage rate is denoted by $r_t^m$ and depends on the risk free interest rate. It always holds that $r_t^m > r_t$.

Total wealth holdings in the beginning of period t are thus given by

$$w_{i,t} = (1+r_t)a_{i,t} + p_t h_{i,t} - (1+r_t^m)m_{i,t}$$

In every period, households holding an existing mortgage of size $m_t$ choose their debt repayment. For their repayment schedule they have to respect the constraint that the minimum amount of repayment per period, $M_{i,t}$, delivers linear and full repayment of mortgage debt until the household dies with certainty after age T+TR. $M_{i,t}$ satisfies

$$M_{i,t} = m_{i,t} \left[ \sum_{j=1}^{T+TR-\tau_{i,t}} \prod_{k=0}^{j} \frac{1}{(1+r_{t+k}^m)} \right]^{-1}$$

This assumption is in line with Kinnerud (2022) and Wong (2019).[7] The repayment choice of an existing mortgage is therefore constrained to

$$m_{i,t+1} \leq (1+r_t^m)m_{i,t} - M_{i,t}. \tag{2.1}$$

[7]Our descriptive results in Figure 2.2 of Section 2.3.2 confirm that mortgage repayments last until high ages in life.

We assume that mortgage rates are fully flexible. This assumption is equivalent to a scenario where all households with existing mortgages decide to refinance their mortgage whenever mortgage rates drop. In our analysis we only consider interest rate declines and no increases, which makes the assumption of flexible mortgage rates plausible.
Households have to pay fix costs whenever they change home ownership status or their owned house size. If a new home is purchased, the fix costs $F(h_{i,t+1})$ are proportional to the value of the new home. If a transition from homeowner to renter is made, the fix costs depend on the quality of the sold home, i.e. $F(h_{i,t})$.

## Housing choice

The choice for housing services is discrete, i.e. $s_{i,t} \in \{s_1, s_2, ..., s_{sn}\}$.
If households own a home, the quality of housing they enjoy is equal to their home size or quality, i.e. $s_{i,t} = h_{i,t+1}$. The set of possible owned home sizes is a subset of s: $h \subset s$ (see Kinnerud, 2022). More specifically, the minimum possibly owned home quality is larger than the minimum possibly rented home quality.
Households, which are not homeowners, can choose the quality or size of housing services $s_t$ from the set $s$ in every period. The price for renting one unit of housing services in a specific period t is given by $p_t^r$ and co-moves with the house price $p_t$.

## Interest rates and prices for housing services

The mortgage rate is determined by the risk free interest rate plus a mortgage spread, $\kappa$:

$$r_t^m = r_t + \kappa. \tag{2.2}$$

## Optimization problem

In every period, an individual i chooses its housing status $h_{i,t+1} \geq 0$ , the size of housing services $s_{i,t}$, the amount of illiquid assets $a_{i,t+1}$ and the mortgage size $m_{i,t+1}$, if the household decides to own a home. The state variables the household faces are given by the vector $z_{i,t} = \left\{\tau_{i,t}, y_{i,t}, a_{i,t}, h_{i,t}, m_{i,t}\right\}$. $z_{i,t}$ includes age $\tau_{i,t}$, labor income $y_{i,t}$ current asset holdings $a_{i,t}$ and $h_{i,t}$ as well as mortgage size $m_{i,t}$.

Formally, the value function of a renter is given by

$$V(z_{i,t}|h_{i,t}=0) = \max\Big\{V^{rent}(z_{i,t}), V^{purchase}(z_{i,t})\Big\}.$$

The renter compares its expected lifetime utility for the options of staying renter or becoming homeowner. A homeowner faces

$$V(z_{i,t}|h_{i,t}>0) = \max\Big\{V^{rent}(z_{i,t}), V^{purchase}(z_{i,t}), V^{keep}(z_{i,t})\Big\}.$$

In addition to the choice of becoming renter or purchasing a home of a different size than the current one, the homeowner can decide to stay in her home and to repay the existing mortgage according to the minimum repayment requirement given by equation 2.1. The Bellman equations given the decisions to rent, purchase or keep a home in a given period are displayed in Appendix 2.C.
The model is solved using an algorithm based on Druedahl and Jørgensen (2017). A description of the algorithm used can be found in Appendix 2.D.

## 2.4.2 Calibration

We calibrate the model to match empirical moments on labor income processes and home ownership rates for the years 1999 and 2001 as a baseline. We consider these years, as the 1990s were relatively stable in interest rates and house prices. Thus considering data on the end of this decade might be worthwhile for a calibration of an initial steady state.
A model period is five years. This implies 9 working periods from age 20 to 64 and 3 retirement periods until certain death after the age of 79. We assume that for working age households up to the age of T-1 the probability to die in the subsequent period is zero. Survival probabilities during retirement are estimated using the Human Mortality Database.
Table **??** shows the parameter values, which we set exogenously. The preference parameter $\epsilon$ is set to 0.8, which implies an unconstrained ratio of durable to non-durable consumption of 0.25, (see Davis and Ortalo-Magné, 2011; Paz-Pardo, 2024). Following Kinnerud (2022) we set the inter-temporal elasticity of substitution parameter $\sigma$ equal to 2. As a standard value for an annual discount factor we use 0.99, which implies $\beta = 0.961$ in our case.

| Exogenous parameters | | |
|---|---|---|
| **Parameter** | **Value** | **Source** |
| Demographics and household preferences | | |
| T | 9 | Working age from 25 to 65 |
| TR | 3 | Retirement age from 70 to 85,Wong (2019) |
| $\sigma$ | 2 | Kinnerud (2022) |
| $\epsilon$ | 0.8 | Paz-Pardo (2024) |
| $\beta$ | 0.951 | |
| Labor income | | |
| $\rho$ | 0.624 | annual Wong (2019) |
| $\sigma^2$ | 0.0716 | annual Wong (2019) |
| Housing | | |
| $p_t^r$ | 0.25*$p_t$ | Davis et al. (2008) |
| Mortgage | | |
| $\lambda$ | 0.8 | Luengo-Prado (2006) |
| $\kappa$ | 0.014 | annual Kinnerud (2022) |

Table 2.5: Exogenous parameters

For the deterministic part of the labor income process, $\omega(\tau)$, we fit a second order polynomial to the median earnings of the households aged 20 to 65 observed in the PSID data.[8] We use the values for the idiosyncratic components $\rho$ and $\sigma_\eta^2$ from Wong (2019) and translate them to a time period of 5 years.

The initial steady state price for one unit of housing $p_t$ is normalized to 1 and the rental price for home is set to 25% of $p_t$. This number is chosen in line with Davis et al. (2008), who find that the annual rent-price ratio of owner-occupied housing has been relatively stable at around 5% until the 1990s.

We impose a minimum down payment constraint of 20% of the house value, which is a standard value used in the literature (see e.g. Kinnerud, 2022; Luengo-Prado, 2006; Paz-Pardo, 2024; Wong, 2019). We set the annual mortgage spread to 0.014, in line with Kinnerud (2022), and the fix costs of house adjustment to 5% of the house value, following Wong (2019).

We set the number of housing qualities to 3, whereas the lowest home quality can only

[8]We use total family income as a variable for earnings.

be rented and not be purchased. The housing grid is chosen such that the median home value to income ratio among homeowners is equal 2.3.[9] This corresponds to the median house value to median income ratio empirically observed in the PSID data for the years 1999-2001. Data from Fred St. Louis confirm this number in calculations using the Case-Shiller index and median labor incomes.
We match the initial wealth holdings to the liquid wealth to income ratio of young individuals observed in the PSID data for the years 1999-2001. To do so, we fit a Weibull distribution to the data and draw initial liquid wealth to income ratios for the youngest simulated individuals aged 25-29.

We are left with three parameters to be calibrated internally: the bequest parameters $B_1$ and $B_2$ and the preference parameter for home ownership, $\chi$.
We calibrate all parameters jointly to minimize a Loss function on the difference of the simulation outcome to the empirical estimates on three moments. These moments are the median liquid wealth held by retirees relative to median liquid wealth holdings of young individuals, the fraction of households aged T+TR leaving a bequest smaller than their annual retirement income and the overall home ownership rate.
Table 2.6 relates the empirical moments to the endogenous parameters. It also shows the calibrated parameter values as well as the empirical and simulated moments.

| **Endogenous parameters** | | | | |
|---|---|---|---|---|
| **Parameter** | **Estimated moment** | **Param. val.** | **Data** | **Simulation** |
| $\chi$ | Home ownership rate | 1.24 | 0.71 | 0.71 |
| $B_1$ | Frac. old households leaving beq < annual income | 7.8 | 0.099 | 0.098 |
| $B_2$ | Median. liq assets holdings of retirees/median liq asset holdings of workers | 4.4 | 3.34 | 3.77 |

Table 2.6: Endogenously calibrated parameters

Our calibration yields the initial age-dependent home ownership rates shown in Figure 2.6. The simulation results feature a stronger curvature in home ownership over the life cycle.
Initial home ownership might be lower in the model compared to the data, because we do not include bequests in our model. In addition, mortgage requirements were sluggish in the years before the financial crisis, leading to comparably high home ownership rates among young households with few wealth holdings in the data.

[9] We intend the second housing quality to be median owned home size.

In order to match a home ownership rate of 71%, the middle aged generations compensate for the too low home ownership rate among the young generations by too high home ownership compared to the data.

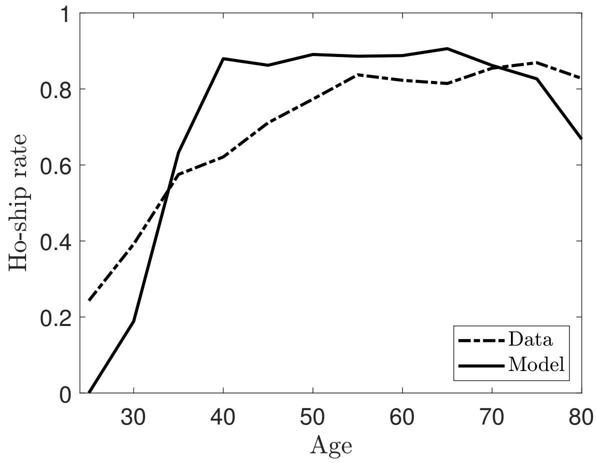



Figure 2.6: Home ownership rates by age generated by the model vs PSID data 1999-2001.

## 2.5 Unexpected price changes

To understand the transmission of the *down payment channel*, we simulate our model economy under unexpected changes in the house price and the interest rates.

We assume that in period 0, the economy is in a steady state with the real interest rate at 4% annually, which corresponds to the average 3 months treasury yields between 1999 and 2001. The house price is normalized to 1.

Starting from period 1, we simulate the evolution of the model economy under different types of permanent price shocks. By doing so we can observe how generations at different stages of their life cycle in the shock period are affected by the respective shocks.

We first impose a house price shock of 20%. As a second analysis we add a permanent decline in the savings rate from 4% to 1% annually to the house price shock. Keeping the wedge $\kappa$ between the savings rate and the mortgage rate, also the mortgage rate declines in this scenario.

To show that the dominance of the mortgage rate decline or the savings rate decline depends on the size of house price inflation, we assume an increase in house prices in period 1 by 35% together with the decline in interest rates described above in a last simulation.

### 2.5.1 A moderate increase in house prices by 20%

As a first experiment, we assume that the economy is in a long-run equilibrium, before in the beginning of period 1 the price for housing increases by 20%.
We can now investigate the evolution of home ownership decisions in a period, where some (older) generations were alive during the shock and other (younger) generations were born after the shock. The transitional and short run perspective might give important insights in the redistributive consequences of house price inflation across generations.[10]
Figure 2.7 depicts home ownership rates (left graph) and liquid wealth to income ratios (right graph) across age groups under the initial scenario (solid lines) and 15 years (3 periods) after the house price has increased unexpectedly (dashed lines).

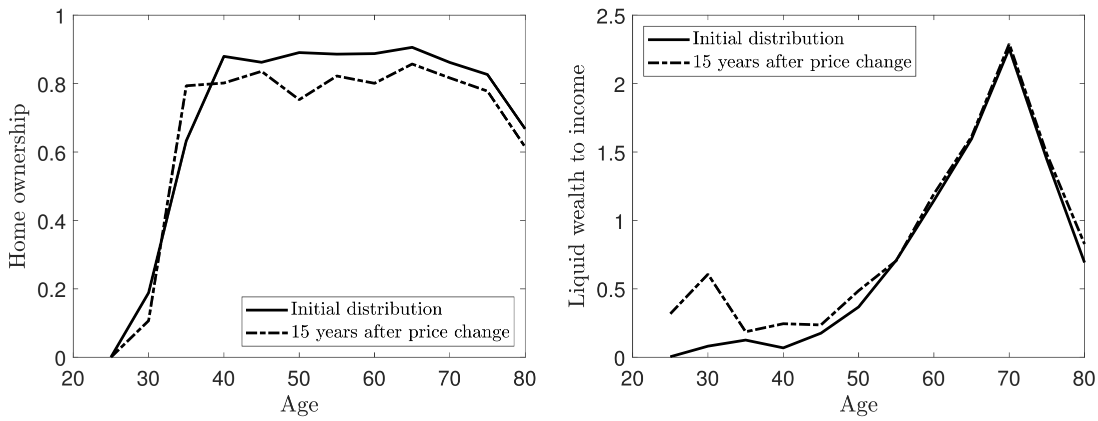



Figure 2.7: Home ownership rates and liquid wealth to income ratios by age for initial scenario (solid line) and 15 years (i.e. 3 periods) after change in house price by 20%

Home ownership rates among middle aged and old households are below the initial long-run levels 15 years after the house price shock. For all individuals starting from the generation aged 35-39 (Age 39 on the x axis) in the after-shock period considered, the price shock has hit them while they have been alive already for at least one period. The young generations by the time of the shock did not anticipate the increase in the

[10]In Appendix 2.E we compare the long-run characteristics of different cohorts before and after the house price shock.

required down payment size and therefore were less likely to afford a home after period 1. As a result, home ownership rates among the middle-aged households are below the levels of the initial house price scenario.
The households that are retired 15 years after the shock hold fewer houses for a different reason. Many of them were homeowners already, as the house price shock occurred. They experienced a substantial wealth increase, as their home value has increased by 20%, while their mortgage volume has remained at its old level. In order to consume a fraction of the additional wealth, part of the elderly homeowners sell their indivisible home.
All generations born at the time or after the shock (generations aged 20-24, 25-29 and 30-34) accumulate substantial liquid wealth to meet the down payment requirement for the housing mortgage. Their average liquid wealth to income ratios are therefore well above the levels of their corresponding pre-shock cohorts.
We can observe that wealth accumulation for the down payment last longer after the shock. This is is why some of the twenty to thirty year old agents postpone their home purchase to the age of 30-34. At this age the liquid wealth to income ratio declines rapidly, because the down payment is made. As a result, liquid savings are hump-shaped in the first decades of the working life.
Among the age group 35-39, more households own a home than before the shock. This is because rental prices have increased in line with house prices. The increased cost for rents make home purchases more attractive.

The shock has different effects on individuals across the life cycle, depending on their savings and housing status. The liquid savings of individuals plays a crucial role when it comes to the decision, whether households can still afford a home after the price increase. As home ownership rates increase substantially when individuals reach their early thirties, it is worth to consider more in detail the generation aged 30-34 as house prices increase unexpectedly.

Instead of comparing characteristics of different cohorts at a specific point in time, we now consider the housing choice and savings of one generations over its entire life cycle. In Figure 2.8 the life cycle evolution of average home ownership rates and liquid wealth to income ratios is displayed for two different generations: the one that experiences the home price shock at the point in time they are aged 30-34 (solid lines) and for the generations that are born after the shock (dashed lines).
The latter generations take into account the high down payment requirements and accumulate substantial wealth in their first working life periods already. The older

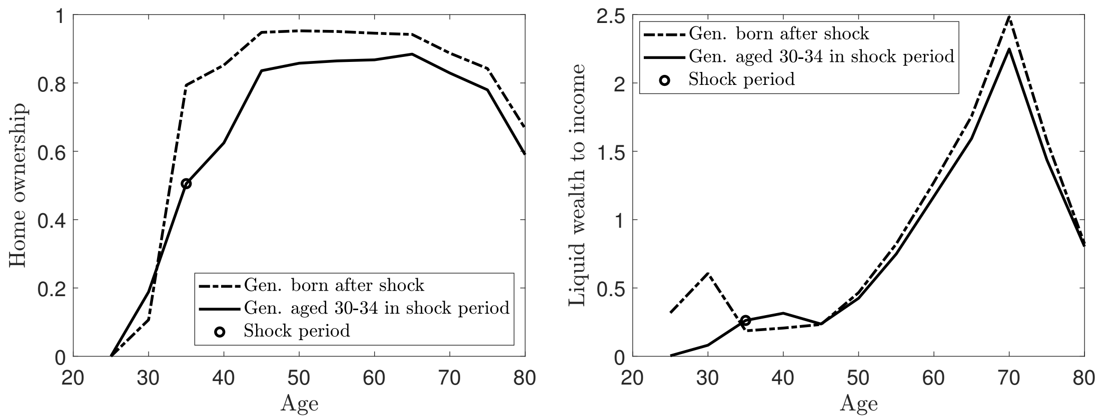



Figure 2.8: Home ownership rates and liquid wealth to income ratios by age for two different generations, aged 30-34 (solid line) in shock period and born after house price shock (dashed line). *o* marks the age at which the existing generation is hit by the shock.

generation has much lower liquid wealth to income ratios before the shock and adjusts its saving behavior after the shock (the moment in the life cycle when the shock hits this generation is marked by a circle).

Compared to the cohorts born after the shock, the older generation considered reaches its maximum average home ownership rate at a lager stage in life. This is due to a longer period of savings accumulation until the mid fourties. At this age, liquid wealth to income ratio falls, as the down payment for the home is made. Overall, the age cohort born before the shock exhibits lower home ownership rates over most of the life cycle and also accumulates fewer liquid assets.[11]

## 2.5.2 An increase in house prices and a decline in interest rates

In a next experiment we consider a simultaneous increase in the house price and a decline in the real interest rate by 3 percentage points annually, thus declining form 4% to 1% annually. The mortgage rate is such that the five year spread between the the two interest rates is the same as in the initial long run scenario.

[11]If we considered generations aged 25-29 or 35-39 as house prices increased unexpectedly, we would obtain similar results, as these generations were also in a deterministic phase of their life cycle for their home ownership decision, as house prices increased.

The simultaneous decline in both interest rates in our model entails two channels[12] that affect individuals' housing and savings decisions: these are an intra-temporal substitution effect and an income effect.

*Intra-temporal substitution effect*: As both the returns to savings and the mortgage rate decline, saving becomes less attractive, whereas borrowing becomes more attractive. This results in a reduction in liquid savings and an increase in the mortgage balance making housing more easily affordable and therefore increasing home ownership rates.

*Income effect*: Savings accumulation to meet the down payment requirement takes longer, as the return to savings declines. Individuals therefore defer home purchases or increase their savings rate or a combination of both. This would imply a reduction in home ownership rates among the younger generations. We call this channel the *down payment channel*. The *down payment channel* gains importance if house prices and required down payments are high.

As we have seen, the two effects have opposed implications on home ownership and savings. It is worthwhile to consider two scenarios of house price increases, in which different effects dominate, respectively. In a first scenario with a moderate increase in house prices of 20% within five years (one period), the intra-temporal substitution effect dominates the income effect, leading to higher home ownership rates across all age groups. In contrast, the second scenario with 35% house price inflation leads to a decline in home ownership rates among the youngest generations. Here the income effect dominates as the down payment volume increases strongly.

The two scenarios are related to our previous empirical analysis in Section 2.3.3, where we distinguish between U.S. states with house price inflation below 50% and above 50% in the 2010s. The median increase in house prices in the low house price inflation state was around 41% and the median increase in high house price inflation states was 84%[13] between 2011 and 2019, which roughly translates into an increase of 20% and 35% within five years, respectively.

[12]As a third channel an *inter-temporal substitution effect* can be detected: As the return to savings declines, saving becomes less attractive and individuals prefer higher instantaneous consumption. Thus the liquid wealth to income ratio drops according to this channel. The effect has an indirect impact on housing decisions, but is not in the spotlight of our analysis.

[13]We use the Zillow Home Value index obtain these numbers, where we consider the dataset taking into account the 35 to 65 quantiles of all home transactions.

## 20% house price inflation

The life-cylce pattern of home ownership and liquid asset holdings in Figure 2.9 differs substantially from the pattern in Figure 2.7. In both Figures the house price increases by 20%. In the former case the return to savings as well as the mortgage rate decline in addition, whereas in the latter case the interest rates remain constant.

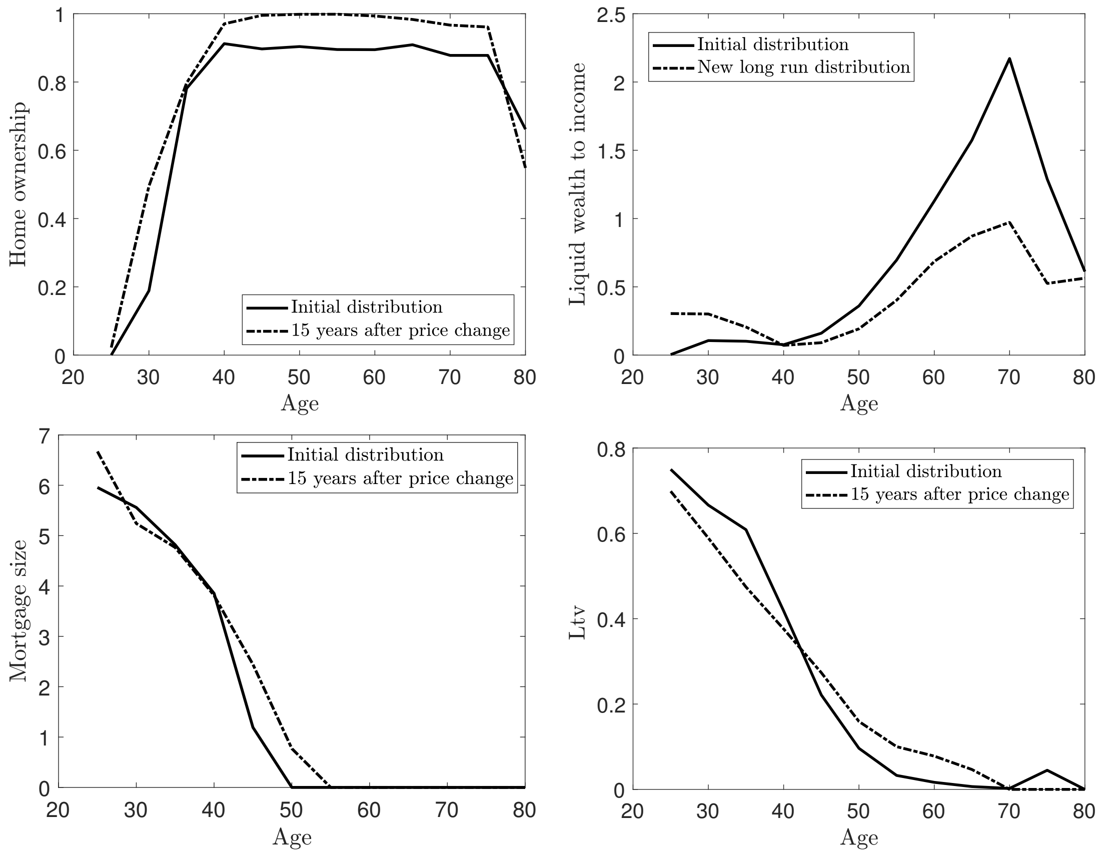



Figure 2.9: Home ownership rates, liquid wealth to income ratios, median homeowner mortgage volumes and median ltv ratios by age for initial steady state (solid lines) and 15 years (i.e. 3 periods) after change in house price by 20% and interest rate shock by 3p.p. (dashed lines)

Considering home ownership first, the recent scenario containing the drop in interest rates shows an increase in home ownership rates among almost all generations 15 years after the shock relative to the pre-shock scenario. For the young generations the decline in interest rates (more specifically in mortgage rates) is beneficial, as it makes home purchases more affordable. In this case the *intra-temporal substitution effect* dominates the *income effect*, which leads to the increase in home ownership rates among younger generations below the age of 50. The depressing effect of the *down payment channel* on home ownership rates weaker than the positive *intra-temporal substitution effect*. Middle aged and old households keep their home until late ages, as they can borrow against their home and thus maintain a high consumption level. Consequently, mortgage rates of homeowners (bottom left graph) decline at a lower pace than in the pre-shock scenario.[14]

Very young households accumulate more savings in terms of liquid assets due to the increase in the down payment requirement. However the mortgage volumes of these age groups show only a little increase after the shock compared to the scenario of low house prices. Thus young home purchasers adjust their loan to value (ltv) choice downwards when purchasing their house in times of high house values: Households reduce their precautionary liquid savings and shift a higher weight of their asset portfolio towards housing. Middle-aged and old age cohorts hold lower liquid wealth after the shock for two reasons. First, lower returns to savings make liquid wealth holdings less attractive;[15] and second, households expect to hold large amounts of liquid assets after they sell their home.

## 35% house price inflation

We now consider a stronger drop in the house price, namely by 35% in period 1. As mentioned earlier, this corresponds to the median house price increase of above 80% within a decade among the U.S. states with high house price inflation. High house price inflation states are characterized by an increase in home prices by more than 50% between 2010 and 2019.

Our results show that the *down payment channel* gains importance if house price inflation becomes more extreme. As opposed to the age-dependent home ownership rates in Figure 2.9, the fraction of homeowners among the generations up to the age of forty is below the pre-shock numbers. In this case the negative income effect from a higher down payment constraint (i.e. the *down payment channel*) outweighs the positive intra-temporal substitution effect on home ownership rates.

Correspondingly, among the young generations liquid wealth to income ratios as well as mortgage volumes exceed the levels observed in the previous section.

Our theoretical analysis shows that house price inflation has heterogeneous effects on

[14] This behavior is beneficial for two reasons: First, saving in terms of liquid assets is less attractive due to the *inter-temporal substitution effect* and, second, mortgage debt is cheaper due to the *intra-temporal substitution effect*.

[15] This is the *inter-temporal substitution* channel.

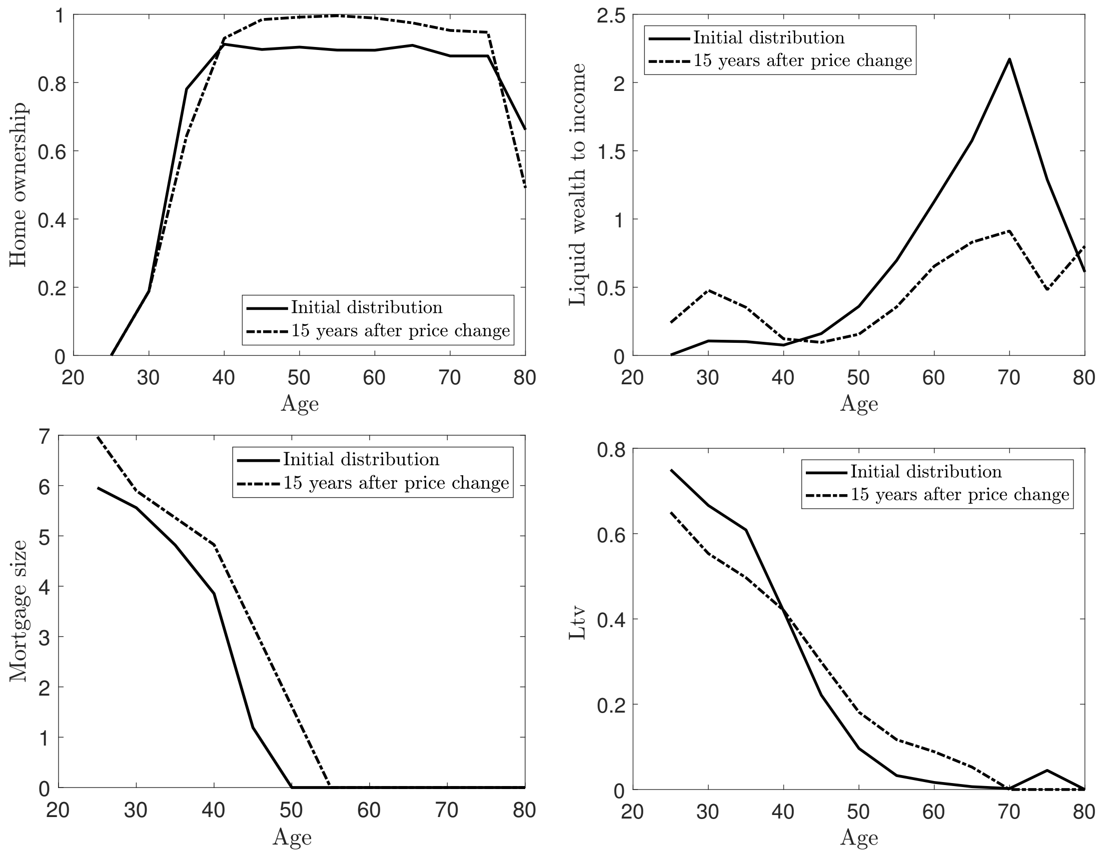



Figure 2.10: Home ownership rates, liquid wealth to income ratios and median homeowner mortgage volumes by age for initial steady state (solid lines) and 15 years (i.e. 3 periods) after change in house price by 35% and interest rate shock by 3p.p. (dashed lines).

home ownership an wealth accumulation across generations: Whereas middle-aged and old homeowners by the time of the shock benefit from an appreciation of their house value, younger individuals have to increase their savings to afford a home and its down payment. This leads to a deferral in home ownership. In combination with a decline in real interest rates, again elderly homeowners benefit from a lower mortgage repayment burden. For younger future homeowners the effect is mixed. On the one hand, low mortgage rates are beneficial for them to purchase high housing debt. On the other hand, low returns to savings reduce the speed of wealth accumulation for their down payment. Which of the opposing effects dominates depends on the degree of house price inflation. In any case, periods of high home values and low interest rates lead to higher debt holdings throughout the life cycle, as individuals borrow against their home, see Bartscher et al. (2020).

## 2.6 Conclusion

In this paper we study the relationship between strong house price inflation, long-term interest rate drops and declining home ownership rates, an environment which has been observed after the financial crisis. Empirically, we find that younger generations face a significantly lower probability to own a home than older generations like the Baby boomers. The latter were mostly home owners already, when house prices increased strongly. Thus their wealth holdings improved from increased home values. In contrast, younger generations with little savings have difficulties to afford housing and to fulfill the down payment requirements for a home. Our empirical analysis further shows that this holds especially true in U.S. states with strong house price inflation above 50% between 2011 and 2019.

During the period considered, interest rates declined steadily and reached a historically low level. Despite the lower mortgage rates, which make housing debt more attractive, home ownership rates declined among young and middle-aged working generations during the low interest phase.

This observation might be explained by the *down payment channel*. Due to a negative income effect from the decline in interest rates, households have to save longer for their housing down payment. Slower savings accumulation leads to a deferral in home purchases.

In our theoretical analysis using a model with housing and mortgage choice we show that this effect is present if house price inflation is very strong. In this case the savings period to fulfill the down payment requirement takes long anyway. In combination with low returns to savings, home purchases are deferred in time even more and the *down payment channel* becomes dominant relative to the home ownership enhancing intra-temporal substitution effect from lower mortgage rates.

Our findings have important implications regarding wealth accumulation over the life cycle and intra-generational inequality. We haven't addressed these issues too much in detail and they are subject to future work. First, regarding life-cycle wealth accumulation, the level wealth holdings over the life cycle shows substantial shifts in wealth towards retired households. Compared to the wealth holdings of young workers at the end of the last century, nowadays young generations generally hold fewer wealth. If households do not participate in asset market with potentially high yields, their life cycle wealth path might be flatter than the path of previous generations. Second, intra-generational wealth inequality is likely to increase in the dimension of home ownership.

As we have seen, home owners gained substantially from their housing asset during the past decades. Renters, however, did not benefit. Furthermore, more and more households tend to store their wealth in terms of low interest bearing assets, which makes wealth accumulation even more difficult for non-home owners.

# References to chapter 2

Adam, K., O. Pfäuti, and T. Reinelt (May 2022b). "Subjective Housing Price Expectations, Falling Natural Rates and the Optimal Inflation Target". *CEPR Discussion Paper No. DP17187.*

Adam, K. and P. Tzamourani (2016). "Distributional consequences of asset price inflation in the Euro Area". *European Economic Review* 89, pp. 172–192.

Arundel, R. (2017). "Equity Inequity: Housing Wealth Inequality, Inter and Intragenerational Divergences, and the Rise of Private Landlordism". *Housing, Theory and Society* 34(2), pp. 176–200.

Barczyk, D., S. Fahle, and M. Kredler (2023). "Save, Spend, or Give? A Model of Housing, Family Insurance, and Savings in Old Age". *Review of Economic Studies* 90(5), pp. 2116–2187.

Bartscher, A. K., M. Kuhn, M. Schularick, and U. Steins (May 2020). "Modigliani Meets Minsky: Inequality, Debt, and Financial Fragility in America, 1950-2016". *CEPR Discussion Paper No. DP14667.*

Davis, M. A., A. Lehnert, and R. F. Martin (2008). "The Rent-price ratio for the aggregate stock of owner-occupied housing". *Review of Income and Wealth* 54(2), pp. 279–284.

Davis, M. A. and F. Ortalo-Magné (2011). "Household expenditures, wages, rents". *Review of Economic Dynamics* 14(2), pp. 248–261.

Druedahl, J. and T. H. Jørgensen (2017). "A general endogenous grid method for multi-dimensional models with non-convexities and constraints". *Journal of Economic Dynamics and Control* 74, pp. 87–107.

Eichenbaum, M., S. Rebelo, and A. Wong (2022). "State-Dependent Effects of Monetary Policy: The Refinancing Channel". *American Economic Review* 112(3), pp. 721–61.

Fischer, M. and M. Z. Stamos (2013). "Optimal Life Cycle Portfolio Choice with Housing Market Cycles". *Review of Financial Studies* 26(9), pp. 2311–2352.

Guvenen, F. and A. A. Smith (2014). “Inferring Labor Income Risk and Partial Insurance From Economic Choices”. *Econometrica* 82(6), pp. 2085–2129.

Kaplan, G., G. L. Violante, and J. Weidner (Apr. 2014). “The Wealthy Hand-to-Mouth”. *NBER Working Paper Series No. 20073.*

Kinnerud, K. (Feb. 2022). “The effects of monetary policy through housing and mortgage choices on aggregate demand”. *Working Paper.*

Kuhn, M., M. Schularick, and U. I. Steins (2020). “Income and Wealth Inequality in America, 1949–2016”. *Journal of Political Economy* 128(9), pp. 3469–3519.

Lian, C., Y. Ma, and C. Wang (2019). “Low interest rates and risk-taking: Evidence from individual investment decisions”. *Review of Financial Studies* 32(6), pp. 2107–2148.

Lisack, N., R. Sajedi, and G. Thwaites (2017). “Demographic Trends and the Real Interest Rate”.

Luengo-Prado, M. J. (2006). “Durables, nondurables, down payments and consumption excesses”. *Journal of Monetary Economics* 53(7), pp. 1509–1539.

Paz-Pardo, G. (2024). “Homeownership and Portfolio Choice over the Generations”. *American Economic Journal: Macroeconomics* 16(1), pp. 207–237.

Webber, K. L. and R. Burns (2021). “Increases in Graduate Student Debt in the US: 2000 to 2016”. *Research in Higher Education* 62(5), pp. 709–732.

Wong, A. (May 2019). “Refinancing and The Transmission of Monetary Policy to Consumption”. *Working Paper.*

Xu, M., J. Alonso-García, M. Sherris, and A. W. Shao (2023). “Insuring longevity risk and long-term care: Bequest, housing and liquidity”. *Insurance: Mathematics and Economics* 111, pp. 121–141.

Zhou, J. (2020). “Household stock market participation during the great financial crisis”. *Quarterly Review of Economics and Finance* 75, pp. 265–275.

# Appendix to chapter 2

# 2.A Further graphs on asset choices

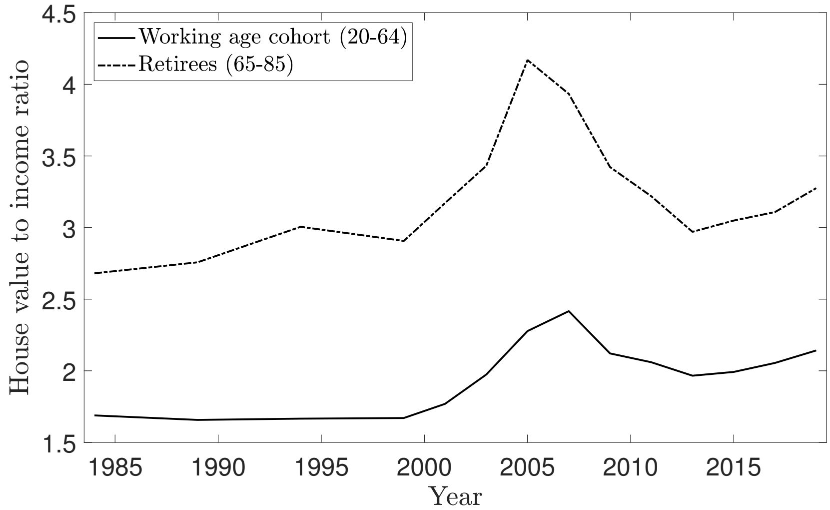



Figure 2.11: House value to income ratios by age cohorts

## 2.A.1 Stock market and *liquid savers*

Figure 2.13 shows that the fraction of households holding *liquid assets* only has been increasing gradually since 1984. We define liquid assets as assets with low returns and little risk, consisting of checking accounts and government bonds.[16] This result is surprising and counter intuitive. It implies that a larger share of the U.S. population saved only in terms of low-return assets - in a period where risk-free interest rates persisted at a very low level.

Figure 2.14 shows the dispersion of all observed households across four types of savers in 1999 and 2019. For the saver categories we distinguish between *liquid assets* and *illiquid assets*, following Kaplan et al. (2014) in the definition for the asset types. Liquid assets contain wealth on checking, saving and money market accounts as well

[16]PSID does not allow to distinguish between the checking accounts and government bonds. The exact question is as following: "Do [you/you or anyone in your family] have any money in checking or savings accounts, money market funds, certificates of deposit, government savings bonds, or treasury bills, including IRA's".

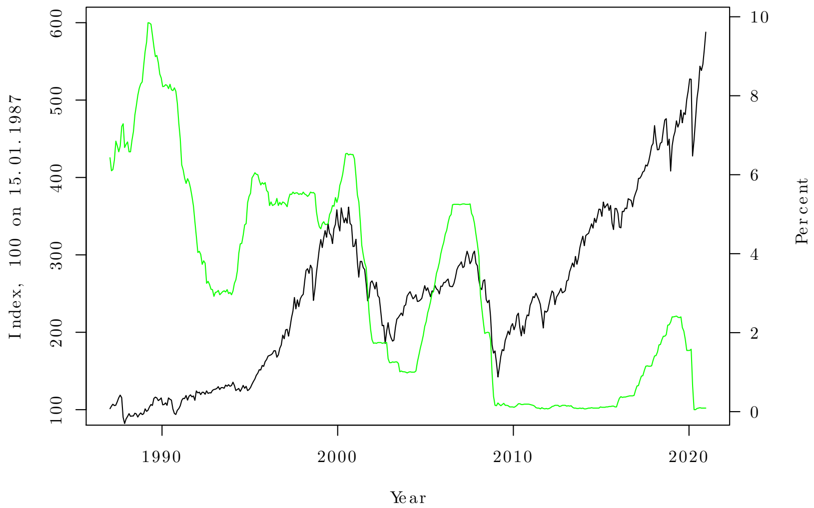



Figure 2.12: S&P 500 index (black) vs Real Federal Funds Rate (green)

as directly held mutual funds, single stocks, corporate and government bonds. Illiquid assets contain home equity, price retirement accounts, life insurance policies and bond funds.

Households are classified in the saver categories depending on their liquid and illiquid wealth holdings. *Poor hand to mouth (HTM)* households hold no illiquid assets. Their liquid asset holdings do not exceed 50% of their total family income.

*Liquid savers* hold more liquid assets than poor HTM types, but they do not hold illiquid assets.

*Wealthy HTM* savers hold not more than 50% of their family income in terms of liquid assets, but they hold positive amounts of illiquid savings. Last, *illiquid savers* are typically the most wealthy households. They hold both substantial amounts of liquid and illiquid savings.

As can be seen in Figure 2.14, from 1999 to 2019 the share of illiquid savers declined by 10 percentage points, whereas the share of liquid saver increased by roghly the same extent. This finding implies that lower home ownership rates did not translate into increased stock market participation or other investments into risky assets with high returns. Instead, a larger fraction of individuals seems to save their wealth in terms of assets with little risk and low returns.

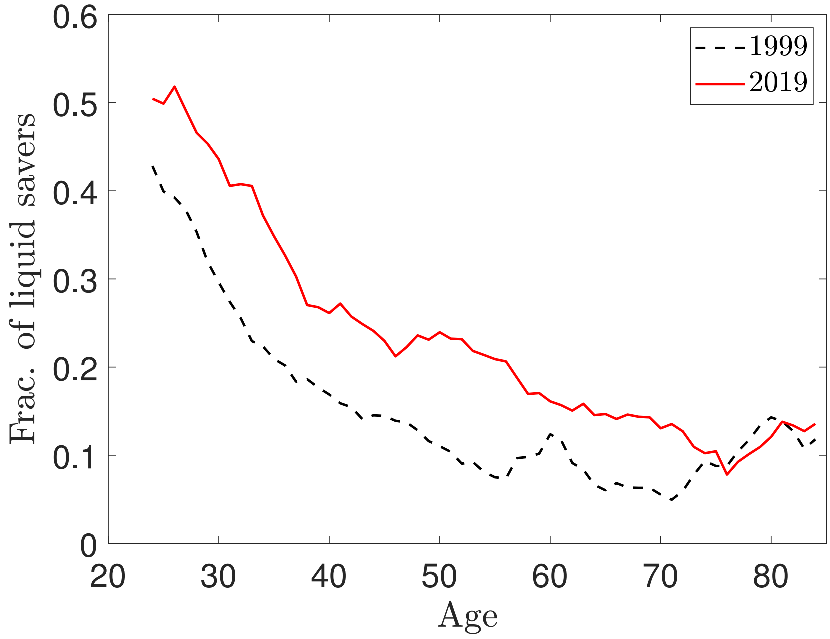



Figure 2.13: Fraction of Savers with only Cash Accounts and Bonds

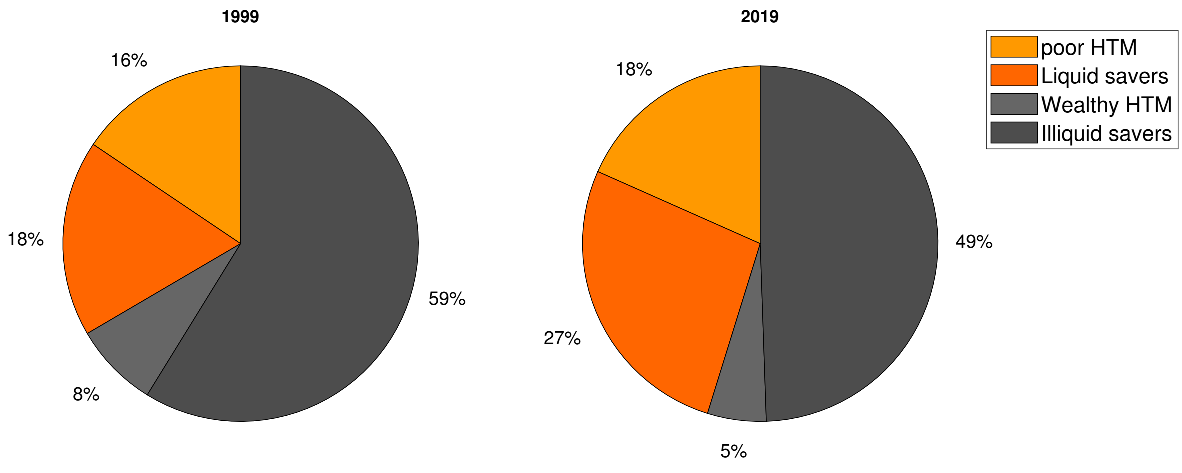



Figure 2.14: Types of savers

# 2.B House price inflation across U.S. states

| State | % Change Zillow index | State | % Change Zillow index |
|---|---|---|---|
| California | 95,94 | Oregon | 83,06 |
| Texas | 61,72 | Oklahoma | 30,63 |
| Florida | 91,14 | Connecticut | 10,22 |
| New York | 38,11 | Utah | 86,31 |
| Pennsylvania | 25,33 | Iowa | 38,68 |
| Illinois | 34,54 | Nevada | 135,89 |
| Ohio | 40,99 | Arkansas | 30,35 |
| Georgia | 74,60 | Mississippi | 27,44 |
| North Carolina | 41,70 | Kansas | 36,27 |
| Michigan | 83,43 | New Mexico | 23,72 |
| New Jersey | 28,36 | Nebraska | 44,99 |
| Virginia | 31,75 | Idaho | 101,74 |
| Washington | 80,24 | West Virginia | 19,16 |
| Arizona | 103,32 | Hawaii | 49,48 |
| Massachusetts | 47,27 | New Hampshire | 41,17 |
| Tennessee | 55,91 | Maine | 36,71 |
| Indiana | 44,26 | Rhode Island | 40,99 |
| Maryland | 32,52 | Montana | 52,81 |
| Missouri | 40,49 | Delaware | 24,69 |
| Wisconsin | 41,73 | South Dakota | 45,25 |
| Colorado | 87,92 | North Dakota | 36,12 |
| Minnesota | 65,16 | Alaska | 27,67 |
| South Carolina | 42,13 | District of Columbia | 60,01 |
| Alabama | 38,26 | Vermont | 26,22 |
| Louisiana | 22,32 | Wyoming | 30,22 |
| Kentucky | 38,08 | | |

Table 2.7: Increase in house prices in different U.S. states 2011-2019

The percentage increase corresponds to the change in the Zillow Home Value Index from 2011 to 2019 for house prices including the 35 to 65 quantile of observations.

# 2.C Bellman equations

$$
\begin{aligned}
V^{rent}(z_{i,t}) = \max_{a_{i,t+1}, s_{i,t}} &\left\{ \frac{\left(c_{i,t}^{\epsilon} s_{i,t}^{1-\epsilon}\right)^{1-\sigma} - 1}{1-\sigma} + \beta \mathbb{E}\tilde{V}(z_{i,t+1}) \right\} \\
\text{s.t.} & \\
c_{i,t} + a_{i,t+1} + p_t^r s_{i,t} =& y_{i,t} + (1+r_t)a_{i,t} - (1+r_t^m)m_{i,t} + p_t h_{i,t} - F(h_{i,t}) \\
\mathbb{E}\tilde{V}(z_{i,t+1}) =& \big(1 - d(\tau_{i,t+1})\big)\mathbb{E}V(z_{i,t+1}) + d(\tau_{i,t+1})v(w_{i,t+1}) \\
v(w_{i,t+1}) =& \frac{B_2\left(B_1 + w_{i,t+1}\right)^{1-\sigma}}{1-\sigma} \\
w_{i,t+1} =& (1+r_{t+1})a_{i,t+1} \\
F(h_{i,t}) =& 0 \text{ iff } h_{i,t} = 0 \\
log(y_{i,t}(\tau_{i,t})) =& \omega(\tau_{i,t}) + \eta_{i,t} \text{ for } \tau_{i,t} \in \{1, ..., T\} \\
\eta_{i,t} =& \rho \eta_{i,t-1} + \psi_{i,t} \\
\psi_{i,t} \sim& N(0, \sigma_\eta^2). \\
y_{i,t}(\tau_{i,t}) =& \phi(y_{i,t-(\tau_{i,t}-T)}) \text{ for } \tau_{i,t} \in \{T+1, ..., T+TR\} \\
a_{i,t} \geq& 0 \ \forall t.
\end{aligned}
$$

$$
\begin{aligned}
V^{purchase}(z_{i,t}) =& \max_{a_{i,t+1},h_{i,t+1},m_{i,t+1}} \left\{ \frac{\left(c_{i,t}^{\epsilon}\chi s_{i,t}^{1-\epsilon}\right)^{1-\sigma} - 1}{1-\sigma} + \beta\mathbb{E}\tilde{V}(z_{i,t+1}) \right\} \\
&\text{s.t.} \\
c_{i,t} + a_{i,t+1} + p_t h_{i,t+1} - m_{i,t+1} =& y_{i,t} + (1+r_t)a_{i,t} - (1+r_t^m)m_{i,t} + p_t h_{i,t} - F(h_{i,t+1}) \\
s_{i,t} =& h_{i,t+1} \\
m_{i,t+1} \geq & -\lambda p_t h_{i,t},\ \lambda \in (0,1),\ m_{t+1} \leq 0 \\
\mathbb{E}\tilde{V}(z_{i,t+1}) =& \big(1 - d(\tau_{i,t+1})\big)\mathbb{E}V(z_{i,t+1}) + d(\tau_{i,t+1})v(w_{i,t+1}) \\
v(w_{i,t+1}) =& \frac{B_2\Big(B_1 + w_{i,t+1}\Big)^{1-\sigma}}{1-\sigma} \\
w_{i,t+1} =& (1+r_{t+1})a_{i,t+1} + p_{t+1}h_{i,t+1} - (1+r_{t+1}^m)m_{i,t+1} \\
log(y_{i,t}(\tau_{i,t})) =& \omega(\tau_{i,t}) + \eta_{i,t} \text{ for } \tau_{i,t} \in \{1,...,T\} \\
\eta_{i,t} =& \rho\eta_{i,t-1} + \psi_{i,t} \\
\psi_{i,t} \sim & N(0,\sigma_\eta^2). \\
y_{i,t}(\tau_{i,t}) =& \phi(y_{i,t-(\tau_{i,t}-T)}) \text{ for } \tau_{i,t} \in \{T+1,...,T+TR\} \\
a_{i,t} \geq & 0\ \forall t.
\end{aligned}
$$

$$
\begin{aligned}
V^{keep}(z_{i,t}) &= \max_{a_{i,t+1},m_{i,t+1}} \left\{ \frac{\Big(c_{i,t}^{\epsilon}\chi s_{i,t}^{1-\epsilon}\Big)^{1-\sigma}-1}{1-\sigma} + \beta\mathbb{E}\tilde{V}(z_{i,t+1}) \right\} \\
&\text{s.t.} \\
c_{i,t}+a_{i,t+1}+p_t h_{i,t+1}-m_{i,t+1} &= y_{i,t}+(1+r_t)a_{i,t}-(1+r_t^m)m_{i,t}+p_t h_{i,t} \\
s_{i,t} &= h_{i,t+1} = h_{i,t} \\
m_{i,t+1} &\leq m_{i,t}(1+r_t^m) - m_{i,t}\left[\sum_{j=1}^{T+TR-\tau_{i,t}} \prod_{k=0}^{j} \frac{1}{(1+r_{t+k}^m)}\right]^{-1} \\
\mathbb{E}\tilde{V}(z_{i,t+1}) &= \big(1-d(\tau_{i,t+1})\big)\mathbb{E}V(z_{i,t+1}) + d(\tau_{i,t+1})v(w_{i,t+1}) \\
v(w_{i,t+1}) &= \frac{B_2\Big(B_1+w_{i,t+1}\Big)^{1-\sigma}}{1-\sigma} \\
w_{i,t+1} &= (1+r_{t+1})a_{i,t+1}+p_{t+1}h_{i,t+1}-(1+r_{t+1}^m)m_{i,t+1} \\
log(y_{i,t}(\tau_{i,t})) &= \omega(\tau_{i,t})+\eta_{i,t} \text{ for } \tau_{i,t}\in\{1,...,T\} \\
\eta_{i,t} &= \rho\eta_{i,t-1}+\psi_{i,t} \\
\psi_{i,t} &\sim N(0,\sigma_\eta^2). \\
y_{i,t}(\tau_{i,t}) &= \phi(y_{i,t-(\tau_{i,t}-T)}) \text{ for } \tau_{i,t}\in\{T+1,...,T+TR\} \\
a_{i,t} &\geq 0 \ \forall t.
\end{aligned}
$$

# 2.D Algorithm for household policy function

**State variables:**

- Age
- Labor income (stochastic, exogenous)
- Housing status, housing size
- Liq asset holdings, mortgage debt $\Rightarrow$ Construct Cash on hand variable if hh is renter or sells home. For case *keep home*, the mortgage size is explicit state variable.

**Choice variables:**

- Own or rent home next period
- Housing quality next period
- Liquid assets
- Mortg size if hh chooses *own* for next period
- (consumption, determined indirectly through other choices)

Solve optimization problem using backward induction, i.e. starting from last period of household's lifetime go backwards until $\tau = 1$. For each age solve Bellman equation. Steps

1. Loop over all states of home ownership: *not home owner* or *home owner*, where *home owner* entails different owned house sizes.
2. Loop over choices to *rent* ($h_{i,t+1} = 0$) or to *own* ($h_{i,t+1} > 0$) in the current period. This discrete choice will be the home ownership status for next period.

3. Within *rent* and *own* decision, loop over all possible housing qualities for each case. If the household's state and choice is *owner* and the housing quality remains constant, i.e. $h_{i,t} = h_{i,t+1}$, the household has to repay an existing mortgage and has to respect equation 2.1.

4. For the scenario *keep* or *purchase* home, loop over a grid of possible ltv ratios. Do next step and choose ltv ratio that yields largest utility under given owned housing size next period.

5. Given all cases of state an choice variables apply endogenous gridpoint method to determine endogenous grid of state variable *cash on hand* for which exogenous grid of choice liquid assets and all cases from 1. are optimal.

6. For both scenarios *own* and *rent* choose housing quality that yields highest expected future lifetime utility.

7. Given state variable of home ownership status, compare utility of choice *rent* with utility from choice *own* to determine housing choice.

**Tauchen method for varying Markov matrix over the life cycle:** Create a grid of size N with discrete income levels. $omega_\tau$ is the deterministic income component at age $\tau$. The probability of reaching $Y_n$ in period t+1 at age $\tau + 1$ , given that the income level in period t at age $\tau$ is $Y_m$, $n, m \in \{1, ..., N\}$ is

$$Pr\left(Y_{n,\tau+1,t+1}|Y_{m,\tau,t}\right) = Pr\left(Y_n - \omega_{\tau+1} - \rho\eta_t - \frac{1}{2}diff_{n-1} < \psi_{t+1} \leq Y_n - \omega_{\tau+1} - \rho\eta_t + \frac{1}{2}diff_n\right).$$

It follows that

$$Pr\left(Y_{n,\tau+1,t+1}|Y_{m,\tau,t}\right) = Pr\left(Y_n - \omega_{\tau+1} - \rho(Y_m - \omega_\tau) - \frac{1}{2}diff_{n-1} < \psi_{t+1} \leq Y_n - \omega_{\tau+1} - \rho(Y_{m,} - \omega_\tau) + \frac{1}{2}diff_n\right)$$

where $diff_n = Y_{n+1} - Y_n$ is the distance between gridpoint $Y_n$ and the subsequent (bigger) grid point $Y_{n+1}$.

# 2.E Long-run effects of a permanent increase in the house price by 20%

In order to understand the effects of the house price shock on impact, it is helpful to first study its implications on household behavior in the long run.
Figure 2.15 shows the long run evolution of home ownership rates, average liquid wealth to income ratios, mortgage volumes and consumption levels across age groups before the house price increase (solid lines) and in the new long run after the price increase (dashed lines). The latter scenario is reached T+TR periods after the shock, when all individuals alive have been born in the high house price environment and therefore did not experience an unexpected price increase.
As the first graph in Figure 2.15 shows, for the youngest cohorts home ownership rates are lower after the price shock than before. Starting from the age of 35, home ownership rates in a high house price environment exceed the initial rates by up to 5 percentage points. As an increase in the house price leads to a proportional increase in the price for home rentals, households find it more attractive to purchase a home instead of paying lifelong high rental costs.

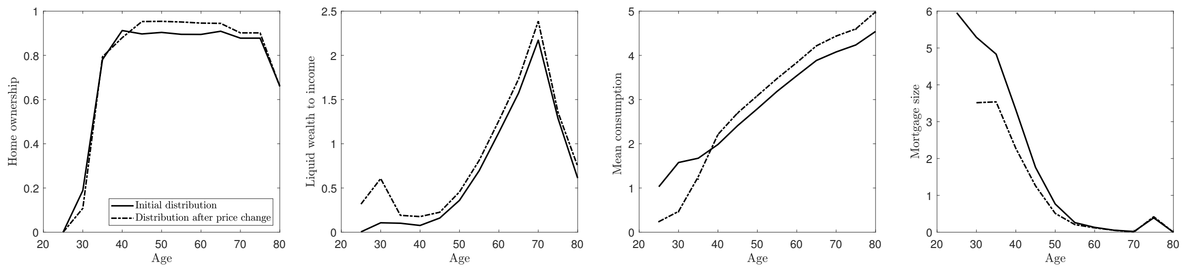



Figure 2.15: Home ownership, liquid asset holdings, mortgage volumes and consumption by age in the long run for low and high home prices.

For young individuals the increase in the house price implies larger savings to meet the down payment requirement for a housing mortgage.
As a consequence, young workers defer their home purchase, which leads to lower home ownership rates among young individuals. The second graph of Figure 2.15 confirms that young generations increase their savings strongly in the high house price environment. Among the 25 to 34 year old workers the liquid wealth to income ratio is well above the average level in the pre-shock scenario. The steep drop in liquid wealth to

income ratios among the mid thirty year old cohorts can be explained by the down payment, which many individuals make at this age.
High initial savings come at a cost with reduced consumption and thus welfare losses for young households, as shown in the third graph of Figure 2.15.
Cohorts aged 35 and older have a larger average liquid wealth to income ratio in the high house price environment than in the low price environment. Furthermore, the third graph in Figure 2.15 reveals that also consumption levels are increased for these age groups. A combination of high savings and consumption levels in a scenario where home prices are at a high level seems counter intuitive. The increased value of the indivisible durable and its implications on inter-temporal consumption smoothing can solve the puzzle, however.[17]
First, liquid wealth to income ratios increase especially among the non-home owners, who face higher rental payments and thus increase their savings over the life cycle. Workers do so to make sure to be able to pay their rent in case of a negative income shock. Furthermore, workers accumulate more savings for their retirement period, as retirement benefits are typically below labor incomes.
Second, owners compensate for their forgone consumption during the down payment accumulation phase by high consumption level at older ages. As housing is a indivisible asset, part of the old retirees sell their home in order consume part of their housing wealth.
In the years before the house is sold, retirees anticipate future high consumption and consume more even before the home is sold. This can be only sustained if debt repayment is low. Thus mortgage volumes must be low such that middle-aged and elderly households can benefit from a high consumption level.

[17]Note that we calibrate the model such that the majority of households chooses the lower of the two housing qualities, which can be owned. Therefore we do not take into account the channel of home quality reduction, as house prices increase.

# Chapter 3

# Firm Market Power and Non-homothetic Preferences: Implications for Relative Prices


## Abstract

Prices for necessity goods tend to respond more strongly to variation in inflation than prices for luxuries, which may be a pricing response of firms to changes in household demand elasticities for different types of goods.
A model with monopolistic competition and non-homothetic preferences can replicate asymmetric price responses to a negative TFP shock accompanied by a negative income effect. As the shock hits the economy, demand elasticities decline strongly for goods with high levels of subsistence. Firms producing these goods take into account inelastic demand responses in their pricing decisions and increase their markups. As a result, relative prices of goods with a high degree of necessity increase.



I am grateful for the useful advice from and discussions with Martin Wolf and Volker Hahn.

# 3.1 Introduction

Empirical literature on the relationship between the wealth and income distribution and inflation heterogeneity has been growing over the past years (see e.g. Fessler et al., 2023; Jaravel, 2021; Tavares, 2021). Different potential sources of varying price indices for individuals have been identified by the literature, like differences in preferences (see Braun and Lein, 2020; Kiss and Strasser, 2024) or (spatial) differences in prices for identical goods (see Handbury, 2021; Nord, 2023). Many researchers find that heterogeneity in price indices for different goods and thus in inflation is related to varying consumption baskets along the income distribution. However, little is known about the price setting behavior of firms as a source of varying relative prices in this context.

In this paper I show that a model where firms choose their prices according to the demand elasticities of their specific good can generate the pattern of varying relative prices that can be observed empirically. More specifically, I use a New Keynesian-type of model with monopolistic competition on the firm side and Dixit-Stiglitz preferences including subsistence levels for individual goods on the household side as in Ravn et al. (2008). This implies that preferences are non-homothetic and price markups are endogenous.

In this model setup a negative shock to total factor productivity leads to an increase in relative prices of goods with high levels of subsistence, which can be interpreted as goods with a high degree of necessity.

The negative TFP shock generates a negative income effect. As a result, households reduce consumption, which shifts demand for individual goods towards the level of subsistence for these goods. This leads to a reduction in the price elasticity of demand for individual consumption goods. Firms take the less elastic demand function for their good into account and choose higher price markups and thus higher relative prices. This effect is especially pronounced for goods featuring a high level of subsistence. In contrast, goods with low degrees of necessity reduce their relative prices.

If price frictions are added to the model, heterogeneous nominal price growth of consumption goods with different levels of subsistence can be observed. Given that firms producing goods with high subsistence levels respond to the aggregate shock by increas-

ing their relative prices, nominal price increases of these types of goods are higher than aggregate inflation. For goods with low subsistence levels growth in nominal prices is below average.
I show that this pattern can be observed empirically using CPI data. While price indices of necessity goods tend to overshoot the patterns of aggregate inflation, prices for goods identified as luxuries tend to be less volatile.

My model can explain two observations that have been made empirically in the literature. First, inflation perceived by individuals typically declines along the income distribution, because of varying consumption baskets. For example, Lauper and Mangiante (2023) show that a monetary policy shock triggers heterogeneous inflation rates. The main driver is the strong increase in prices for energy, which make a large share in consumption baskets of households at the bottom of the income distribution. Similar results are obtained by Hochmuth et al. (2023). Second, prices of goods that are consumed to a larger extent by low income groups than by rich individuals tend to be less sticky, more volatile and tend to increase more strongly than prices of goods rather consumed by high income groups. Strasser et al. (2023) show that necessity goods feature above average inflation, which implies higher inflation rates for households that spend a comparably high fraction of their income to these goods. These are typically the low-income groups. Vermeulen et al. (2012) documents for six European countries that producer prices for energy and food adjust more frequently than for other non-durable goods. Both goods are necessities to a high degree, which again implies that price indices for low-income households vary more strongly than for high income households. Cravino et al. (2020) show that prices of goods selling to high income groups respond in a more sticky and less volatile fashion to monetary shocks than other goods. Similarly, Clayton et al. (2018) observe that in sectors where demand increases in the educational level, prices are comparably sticky.
I contribute to the literature by adding a theoretical mechanism to the frequently observed heterogeneity in inflation rates at the expense of poor households. At the same time my mechanism matches the empirically observed variation in prices. The key drivers in my model are non-homothetic preferences and firm market power, which yields endogenous markups, depending on demand elasticities.

This paper is structured as follows. The next section discusses the related literature. In Section 3.3 two empirical patterns on expenditure shares and inflation rates of necessity goods and luxuries are explored. The theoretical model is introduced in Section 3.4. The implications of an inflationary TFP shock are considered in Section 3.5. In Section

3.6 nominal price frictions are introduced to the model. Section 3.7 concludes.

## 3.2 Related Literature

The present paper combines two strands of the literature. The first strand captures literature on heterogeneity of price adjustment and endogenous markups. The second strand of literature is on heterogeneous consumption baskets and ensuing inflation heterogeneity. I link both topics by showing that my model with non-homothetic preferences and firm market power can produce heterogeneous markup choices of firms and a resulting increase in relative prices or necessity goods after a shock entailing a negative income effect.

Focusing on effects on the household side, a broad and increasing literature has been showing that monetary policy affects individuals differently. This is because monetary policy acts through various channels, which have redistributive consequences, see e.g. Auclert (2019), Coibion et al. (2017). Mostly empirical papers are dedicated to the question on the sources and the degree of inflation heterogeneity (see Argente and Lee, 2021; Braun and Lein, 2020; Hochmuth et al., 2023; Kaplan and Schulhofer-Wohl, 2017; Kiss and Strasser, 2024; Tavares, 2021, among others).

The fact that consumption baskets vary across the income and wealth distribution is well known, see e.g. Argente and Lee (2021). Varying consumption shares of different goods across the income distribution can explain a substantial part of the heterogeneity in inflation rates perceived by households, as it shown by Auer et al. (2023), Lee et al. (2022) or Kiss and Strasser (2024). More specifically, goods that are considered to be *necessities* - and therefore make a larger share in the consumption basket of low income individuals compared to high income individuals - tend to feature different price adjustment characteristics than goods that are considered *luxuries*. We will observe this behavior more in detail in the next section.
As mentioned earlier, prominent examples for necessity goods are energy, electricity or food. Lauper and Mangiante (2023) and Hochmuth et al. (2023) show that indeed strong price increases in these good categories can explain high inflation exposure of low income households.

While the household component of inflation heterogeneity has been examined extensively, the different price adjustment responses to an inflationary shock have not been

largely in focus of research.
To identify the source of different degrees of price adjustment, some papers relate goods featuring different degrees of price volatility to the characteristics of their buyers. For instance, Clayton et al. (2018) find that prices of goods selling relatively more to households with a higher educational degree tend to be more sticky. Cravino et al. (2020) come to the same conclusion for high income households and finds that these goods also tend to be more volatile in their prices.
While both use U.S. data from the consumer expenditure survey, Vermeulen et al. (2012) consider European data and observe goods prices classified by item categories. They show that prices for goods in the energy, food and intermediate goods sector are less sticky than prices for other non-durable and durable goods.
If we define food and energy as necessity goods, which all individuals have to consume at a certain level, we can conclude that both approaches, the consumer characteristic approach and the item characteristic approach, yield the same result: Goods consumed at a higher fraction by poorer households (necessities) adjust more frequently in their prices and are more volatile. This might result into stronger price responses of necessity goods to aggregate shocks compared to luxury goods, which are consumed to a larger extent by high income households.
Another approach to identify the source of price variation heterogeneity is to investigate market structures. Arquié and Thie (2023) highlight the impact of market power on the degree of price increases due to inflation driven by rising energy prices. Amiti et al. (2019) emphasize that strategic complementarities are potentially important sources of strong price adjustments.

Turning to the theoretical implications of heterogeneity in price adjustment, some papers show how different price responses affect monetary policy, like Aoki (2001) and Guerrieri et al. (2021). Aoki (2001) considers a New Keynesian model with two sectors, where prices in one sector are fully flexible and in the other sector are sticky to a certain degree. The author finds that optimal monetary policy should not focus on average inflation but focus more on the pricing behavior of the sticky-price sector. As frictions are exogenous, heterogeneous pricing behavior is obtained by construction. In this work I endogenize heterogeneity in price adjustment through different demand elasticities across goods. I abstract from price rigidities, which means that all firms can respond optimally to an aggregate shock. However, including for instance menu costs or price points as in Hahn and Marenčák (2020), my model could generate heterogeneous short-term price stickiness across firms.

Guerrieri et al. (2021) show that a shock to the preferences on relative consumption of two goods generates asymmetric effects on the two goods sectors, similar to a cost-push shock. This breaks *divine coincidence*, which is obtained in traditional New Keynesian models - the outcome that optimal monetary policy can stabilize both inflation and employment simultaneously. As preferences are assumed to be homothetic, all households experience the same level of inflation, irrespective of their income.

Other research puts into spotlight endogeneity of price markups and the implications for monetary policy. Santos et al. (2022), discuss the countercyclical behavior of markups, but do not take into account heterogeneity markups. As mentioned above, Amiti et al. (2019) consider the impact of strategic complementarities on price adjustments and show that firms tend to vary own prices, if their competitors adjust theirs. This finding suggests that firms indeed seem to have a certain degree of market power and take into account demand elasticities (and cross price elasticities) when choosing the selling price of their goods. Meier and Reinelt (2022) use a New Keynesian model with heterogeneous levels of price stickiness across goods to explain the variation in markup dispersion after a monetary shock, which they observe empirically in U.S. firm balance sheet data. The endogeneity and heterogeneity in markups is therefore a result of uncertainty about future price adjustment. The model mechanism can, however, not replicate the empirical patterns of prices for necessities and luxuries, which have been observed in the literature introduced above. More specifically, their model can not explain why prices (and thus markups) of goods with a lower degree of price rigidity are more volatile when adjusted, than prices of goods with a higher degree of price rigidity. To obtain this result in a New Keynesian framework, heterogeneous demand elasticities can be used. These can be obtained by adding non-homothetic preferences over goods or by assuming oligopolistic competition with unequal market shares across firms, as can be seen in Wang and Werning (2022).

## 3.3 Empirical patterns: Expenditure shares and price setting

In this section, I show two empirical patterns for necessity goods and luxury goods. The first pattern is closely related to the definition of necessities vs. luxuries. It displays the evolution of expenditure shares on the two goods types across the income distribution. The second pattern shows the co-movement of prices for necessities and luxuries with aggregate CPI inflation. While the first pattern is well established, the second pattern I present is little explored.

### 3.3.1 Expenditure shares across the income distribution

Necessity goods are defined as goods with a positive income elasticity below one, whereas luxuries entail an income elasticity larger than one. This implies that the expenditure share for necessities declines across the income distribution, whereas the share spent on luxuries increases in income.
I use data from the Consumer Expenditure Survey (CEX) to calculate expenditure shares for typical goods that are considered necessities and luxuries. For my analysis I use annual data from the years 2000 to 2019. I exclude more recent years, as Cavallo (2023) shows that consumption basket composition has varied strongly during the Covid-19 pandemic. The change in consumption bundles was not due to changes in preferences or a response to relative price changes, but largely a result of exogenous restrictions in goods availability.
I choose item categories that are classified as necessities and luxuries, in line with Aguiar and Bils (2015), Hochmuth et al. (2023), Wachter and Yogo (2010) and Orchard (2022).

Figure 3.1 shows the average expenditure shares across income quintiles for three goods that are typically considered necessities. These are food at home, utilities and house keeping supplies. All curves show a clear downward trend across the income distribution. Food and utilities, which have comparably high weights of total expenditures of around 10% for the lowest income quintile, decline gradually in their expenditure share to below 6% among the highest income quintile. The share of housekeeping supplies declines from almost 1.6% to 1.1%, which implies a decline of around 28%.

The selected luxuries in Figure 3.2 are food away from home, entertainment and apparel. For luxuries, the opposite evolution across the income distribution can be observed. Expenditure shares tend to increase, as households become richer. For spending on entertainment, this behavior is clear. Considering food away from home and even

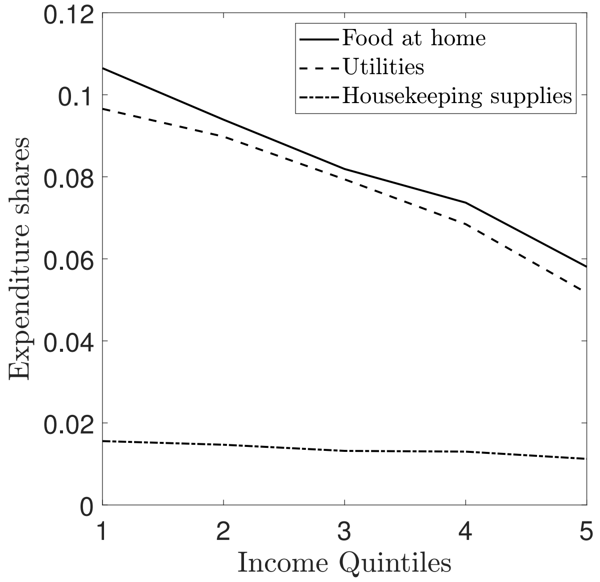



Figure 3.1: Expenditure shares of necessity goods decline across income quintiles

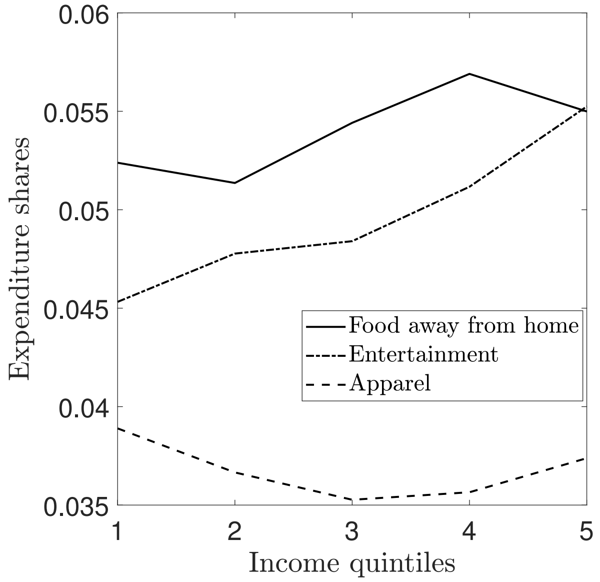



Figure 3.2: Expenditure shares of luxury goods increase across income quintiles

more pronounced in the plot for apparel, we can find a slight U-shape of expenditure shares across income quintiles. This suggests that these goods are not pure luxuries, but include necessities characteristics. For instance, Aguiar and Bils (2015) show that children's clothing can be classified a necessity good, whereas men and women clothing are luxuries.[1]

[1]As can be seen in Figure 3.10 in the Appendix, only men's apparel is monotonically increasing in income for the years I consider.

The above results show that low income households spend a larger fraction of their total consumption on necessities. In contrast, the share of expenditures on luxuries increases along the income distribution. Thus household consumption baskets depend on incomes. In the model I take into account this finding by assuming non-homothetic preferences over different types of goods.

### 3.3.2 Stylized fact: Prices for necessities respond more strongly to inflation than prices for luxuries

After having focused on household expenditures during inflationary periods, we now turn to pricing behavior on the firm side. While the observation that expenditure shares on different items vary along the income distribution has been shown already by the literature, the price responses of necessity goods and luxury goods to inflation are not well explored.
I use data from the Consumer Price Index (CPI), published by the Bureau of Labor Statistics, which is the same source as for our CEX expenditure data. The BLS provides semiannual CPI data on the item category level.[2]
To illustrate the different price responses of luxuries and necessities to periods of inflation, I now combine the two types of goods in the subsequent graphs. Figure 3.3 shows aggregate annual CPI inflation on a monthly basis (in blue) as well as the inflation rates for the categories *food at home* and *food away from home.*

Both categories follow aggregate inflation in their pattern, but *food at home* is much more volatile than *food away from home.* This observation is of special interest, as the input factors for the production of the two sectors are similar. Thus higher exposure to inflation of food produced to be sold for preparation at home can not fully explain this observation.
Figure 3.4 shows a similar pattern. Due to data availability for housekeeping supplies, this graph only includes the most recent inflation period starting from 2021.

Again we can observe that the necessity good (*housekeeping supplies*) responds stronger in its price - and even exceeds aggregate inflation - than the luxuries shown in the graph,

[2] Fewer and broader categories for price indices than for consumer expenditures are publicly available. This is why I do not consider utilities in this section.

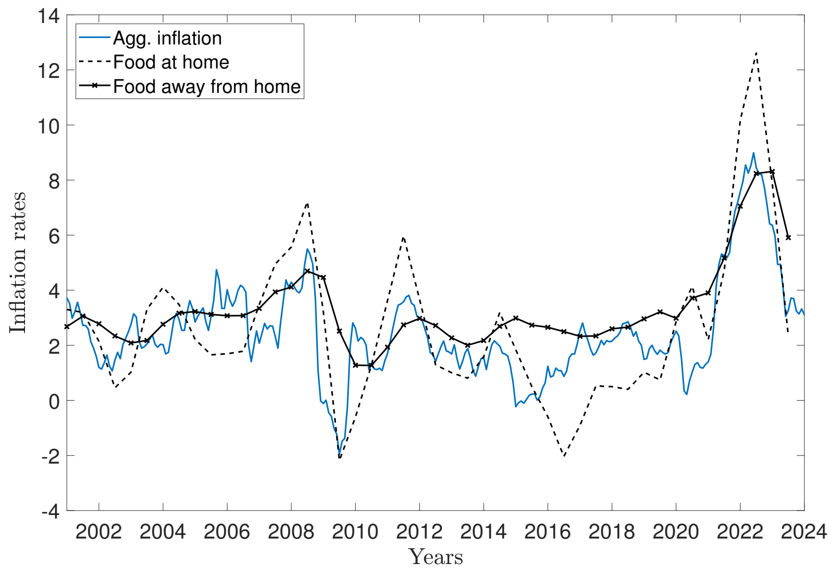



Figure 3.3: Nominal price growth in percent of food at home (necessity good), food away from home (luxury good) and aggregate inflation.

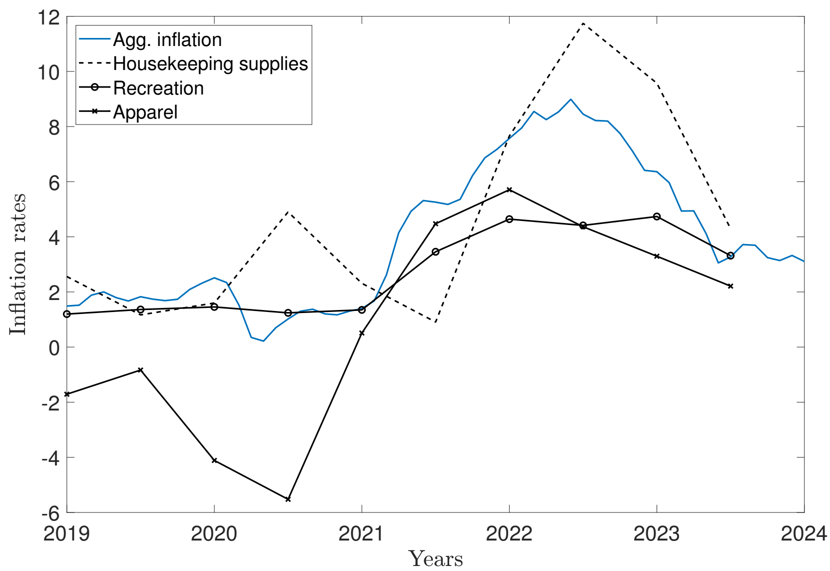



Figure 3.4: Nominal price growth in percent of housekeeping supplies(necessity good), recreation, apparel (luxury goods) and aggregate inflation.

which are *recreation* and *apparel*.

The pattern shown implies that prices of necessity goods relative to the aggregate price level increase, as inflation increases, while the relative prices for luxuries decline.

It is plausible that firms adjust their prices, taking into account the weights of their supplied goods in individual consumption baskets and the resulting income elasticities. By definition, the income elasticity of demand for necessity goods is lower than for luxuries. In case of a shock entailing a negative income effect, firms producing necessities take into account the declined demand elasticity of their goods and choose higher relative prices than firms producing goods facing higher demand elasticity. This suggests that firms have a certain degree of market power. This is why in the model I assume that firms are monopolistic competitors.

## 3.4 Model

In this section, I introduce a theoretical framework that includes non-homothetic preferences and firm market power. Under these assumptions firms take into account the varying demand elasticities for different goods in case of an aggregate shock. This behavior results in heterogeneous adjustments of relative prices. In contrast to standard monopolistic competition with no subsistence levels, a negative and transitory aggregate shock in my model leads to an endogenous shift in consumption towards goods with higher subsistence levels. This happens, whenever a negative income effect hits the households side. Consequently, markups vary endogenously across firms, as demand elasticities vary.

The model features monopolistic competition on the firm side and a Dixit-Stiglitz consumption aggregator with subsistence levels specific to each individual good on the household side, as in Ravn et al. (2008).

**Households** A continuum of households with unit mass has standard CES preferences for an aggregated consumption good. I abstract from heterogeneity on the household side, as it is not necessary to generate the observed price patterns in the data. Thus I consider a representative household here. The household inelastically supplies one unit of labor to firms in each period t.
In each period, the household receives a nominal wage $W_t$ for supplied labor. As there is free labor mobility and a fully competitive labor market in the economy, all firms face the same wage costs. Furthermore, the household owns the firms and receives all firm profits. Aggregate consumption good C is given by a Dixit-Stiglitz aggregator of

individual goods $c_i$ with subsistence levels $\lambda_i$, which are specific to goods type $i$:

$$C_t = \left( \int_0^1 (c_{i,t} - \lambda_i)^{\frac{\epsilon-1}{\epsilon}} \, di \right)^{\frac{\epsilon}{\epsilon-1}}, \tag{3.1}$$

where $\epsilon$ is the elasticity of substitution across goods. Aggregate consumption C can be interpreted as *above subsistence aggregate consumption.* As consumption of the subsistence level $\lambda_i$ of good i is compulsory for the household, it holds that $c_{i,t} > \lambda_i$. The actual choice of the household is the above subsistence consumption level of good i. Households choose individual consumption goods according to a cost minimization problem

$$\min_{c_{i,t}} \int_0^1 p_{i,t} c_{i,t} di$$

subject to equation 3.1. The nominal price for one unit of the individual consumption good is given by $p_{i,t}$.
The first order condition with respect to consumption good i implies

$$c_{i,t} = \left( \frac{p_{i,t}}{\xi_t} \right)^{-\epsilon} C_t + \lambda_i,$$

where $\xi_t$ is the Lagrange multiplier. Feeding this result into the Dixit-Stiglitz aggregator of equation 3.1 and solving for $\xi_t$ yields the standard term for the aggregate price level

$$\xi = \left( \int_0^1 p_{i,t}^{1-\epsilon} di \right)^{\frac{1}{1-\epsilon}} \equiv P_t. \tag{3.2}$$

The individual demand for $c_{i,t}$ is thus

$$c_{i,t} = \left( \frac{p_{i,t}}{P_t} \right)^{-\epsilon} C_t + \lambda_i. \tag{3.3}$$

The result implies that demand for good $c_{i,t}$ contains a constant part $\lambda_i$ and a part that depends on the relative price $\frac{p_{i,t}}{P_t}$, on the elasticity of substitution between goods, $\epsilon$ and on aggregate demand $C_t$.

The price elasticity of demand in absolute terms for good i reads

$$\left| \frac{\partial c_{i,t}}{\partial p_{i,t}} \frac{p_{i,t}}{c_{i,t}} \right| = \epsilon \frac{c_{i,t} - \lambda_i}{c_{i,t}} \equiv \eta_{i,t}. \tag{3.4}$$

The price elasticity of demand depends on the elasticity of substitution parameter $\epsilon$, on the fraction of *above-subsistence* demand relative to total demand for good i and on the market share above good type i's subsistence level. In other words, the share of consumption that accrues to the subsistence level is completely price inelastic, while above subsistence consumption features elasticity in $p_i$. Under zero subsistence levels the demand elasticity would be constant and equal to $-\epsilon$.
The absolute size of demand elasticity $\eta_{i,t}$ decreases in $\frac{\lambda_i}{y_{i,t}}$, implying that households respond weakly to price changes, if demand for their produced good is close to the subsistence level.
We can relate $\eta_{i,t}$ to the aggregate consumption level of the representative household, using equation 3.3: If aggregate demand $C_t$ is low, the relative importance of $\lambda_i$ for $c_{i,t}$ increases and demand for good i becomes less price elastic.

**Firms** Many firms produce the various goods which are consumed by the household, see equation 3.1. Individual firm i uses labor $l_{i,t}$ as an input factor and produces good $y_{i,t}$ according to the production function

$$y_{i,t} = A_t l_{i,t}, \tag{3.5}$$

where $A_t$ is the level of total factor productivity in the economy. We will later assume that there is an unexpected and transitory shock to $A_t$. This assumption yields similar outcomes to assuming that firms use an additional good for production, say energy, which is hit by an exogenous price shock. Such a shock may cause inflation in a model with price frictions (see Fornaro and Wolf, 2023).
The labor market clears if for every period t total labor demand equals labor supply, i.e. $\int_0^1 l_{i,t} di = L_t = 1$. Firms choose prices to maximize profits. Given that goods markets always clear, i.e. $y_{i,t} = c_{i,t}\ \forall i$ as well as $Y_t = C_t$, and using equation 3.3, firm i faces demand for its output good $y_{i,t}$ given by

$$y_{i,t} = \left(\frac{p_{i,t}}{P_t}\right)^{-\epsilon} Y_t + \lambda_i. \tag{3.6}$$

Firm i's optimization problem is given by

$$\max_{p_{i,t}} \Pi_{i,t} = \max_{p_{i,t}} p_{i,t} y_{i,t} - W_t l_{i,t}$$

s.t. equations 3.2, 3.5 and 3.6. Here, $p_{i,t}$ is the firm's nominal price. The first order condition implies

$$y_{i,t} + p_{i,t}\frac{\partial y_{i,t}}{\partial p_{i,t}} - \frac{W_t}{A_t}\frac{\partial y_{i,t}}{\partial p_{i,t}} \overset{!}{=} 0.$$

Inserting equation 3.4, we obtain the optimal price choice

$$\tilde{p}_{i,t} = \frac{w_t}{A_t}\frac{\epsilon}{\epsilon - \frac{y_{i,t}}{y_{i,t}-\lambda_i}} = \frac{w_t}{A_t}\mu_{i,t}, \tag{3.7}$$

where $\tilde{p}_{i,t} = \frac{p_{i,t}}{P_t}$ is defined as the relative price firm i chooses and $w_t = \frac{W_t}{P_t}$ is the real wage. The optimal relative price is a product of marginal costs $\frac{w_t}{A_t}$ and the markup charged by the firm, $\mu_{i,t}$. The firm's markup can be rewritten as a function of demand elasticity $\eta_{i,t}$:

$$\mu_{i,t} = \left(1 - \frac{1}{\eta_{i,t}}\right)^{-1} \tag{3.8}$$

This relationship is a standard result for monopolistic price setting, see also Ravn et al. (2008). However, in this model it is of special interest, as $\eta_{i,t}$ varies in the subsistence share of demand, as can be seen in Figure 3.5.

In the left graph, the demand elasticity is shown as a function of the subsistence share of demand $\frac{\lambda_i}{y_{i,t}}$. The demand elasticity declines, if total demand for good i declines and thus moves closer to $\lambda_i$.

Declining demand elasticity in $\frac{\lambda_i}{y_{i,t}}$ translates into strongly increasing markups. Note that individual firms in a setup with monopolistic power always choose an allocation where demand responds elastically to a price change.[3] Thus firm i will never choose a price for which $\frac{\lambda_i}{y_{i,t}}$ implies that $\eta_{i,t} > 1$ or $\mu_{i,t} < 1$. For the results in Figure 3.5 I choose $\epsilon = 7.5$.[4] Under this parameter specification, the subsistence share of demand for good i must not reach a level well above 0.8.

[3]This is a standard result of profit maximization problems with firm market power, see e.g. Breyer (2015).

[4]The reason for this choice is explained in the next section.

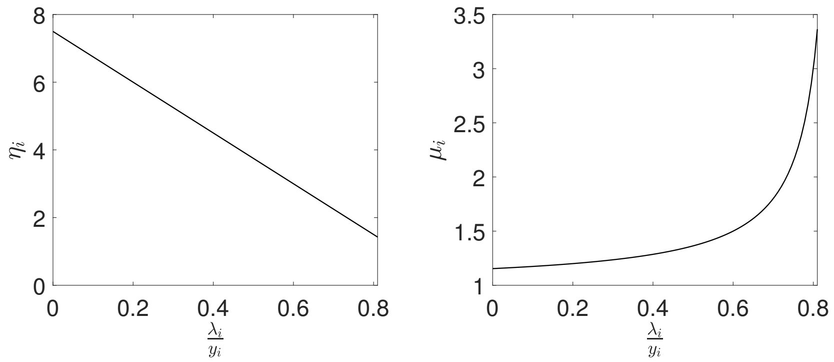



Figure 3.5: Demand elasticities $\eta_{i,t}$ and markups $\mu_{i,t}$ as a function of the subsistence share of demand, $\frac{\lambda_i}{y_{i,t}}$

# 3.5 A negative TFP shock

In this section, I introduce an exogenous and transitory negative shock to the TFP variable $A_t$. The decline in aggregate TFP comes along with a negative income effect to the model economy.[5] As Fornaro and Wolf (2023) show, the TFP shock has similar implications as an increase in the price of imported input factors, e.g. energy. The unexpected hikes in energy prices in 2022 were likely to have contributed to increased inflation in the U.S. and other western economies recently. Thus this kind of shock might have also affected the evolution of relative prices, which we observe empirically. In my analysis I abstract from other potential sources of variation in inflation, such as demand shocks. Demand-sided effects, like e.g. taste shocks, could also generate variation in relative consumption and lead to changes in relative prices. In order to obtain endogenous responses in demand elasticities, I choose a supply-sided transitory shock. I depart from the standard Dixit-Stiglitz aggregator with zero subsistence levels to recapitulate the effects of aggregate TFP shocks in the standard case with homothetic preferences. Then I introduce positive and heterogeneous subsistence levels to the model and show that this extension can generate changes in relative prices across firms.

For simplicity, I assume that prices are fully flexible. Clearly, this assumption is very strong for short term considerations. In the next section, I discuss the model implications of price rigidities.

[5] If instead of a negative shock, a positive TFP shock hits the economy, the income effect is positive and all the results are reversed, see Appendix 3.B.

### 3.5.1 Special case: No subsistence levels

In the standard model with a Dixit-Stiglitz aggregator, firms set their price to be equal to a markup over marginal costs, which is determined by the demand elasticity parameter:

$$\tilde{p}_{i,t} = \frac{w_t}{A_t}\frac{\epsilon}{\epsilon - 1}.$$

Under a fully flexible nominal wage $W_t$, a decline in $A_t$ is fully absorbed by a decline in the real wage $\frac{W_t}{P_t}$. This is because the marginal product of labor drops. As a result, the real wage declines, and relative prices remain unchanged. In this case the negative income effect from declined TFP does not vary relative consumption levels across goods or demand elasticities for the different goods. Relative prices only vary over time, if nominal frictions are added to the model. These can be price or wage frictions. The TFP shock becomes inflationary, if (downward nominal) wage rigidity is introduced to the model. For the real wage to adjust downwards, the price level must increase (see Fornaro and Wolf, 2023). However, relative prices remain constant, as demand elasticities are constant across firms.
Changes in relative prices across firms can only occur if the size of the shock differs across firms, e.g. because energy as an input factor is of different importance to the individual producing firms, or if price frictions are added to the model, which are heterogeneous across firms (see e.g. Aoki, 2001; Nakamura and Steinsson, 2010). In both cases relative price increases of necessities could be obtained by imposed assumptions. In order to understand the mechanism behind the heterogeneity in price responses, non-homothetic preferences need to be taken into account.

### 3.5.2 Full model with subsistence levels

As a next scenario, we assume that subsistence levels for individual goods exist.

An aggregate TFP shock has a negative income effect to the household, which leads to a decline in the demand for all individual output goods.

To illustrate the results, I choose an example where three levels of subsistence exist, which are of equal shares among consumption goods. The subsistence levels I set to $\lambda_1 = 0$, $\lambda_1 = 0.05$ and $\lambda_3 = 0.1$. For total labor supply $L_t = 1$ and initial TFP of $A_0 = 1$ these subsistence levels are chosen, such that the given resources still allow enough

above-subsistence consumption. Firms facing a demand function with subsistence level j are denoted as firms of type j.
The demand elasticity of substitution parameter $\epsilon$ is commonly set to values around 7, which implies a markup of roughly 17% under fully flexible prices in a standard New Keynesian model (see Adam and Weber, 2019a). To obtain similar values in my model with subsistence points, the demand elasticity needs to be slightly higher, at a level of 7.5.
The model economy is hit by a shock in period 1, when aggregate TFP declines by 3 percent. The exogenous path of $A_t$ is set such that the economy recovers linearly to the initial level of 1 in period 13. The duration of a model period can be interpreted as a month. Thus, the aggregate shock vanishes fully after one year.[6]

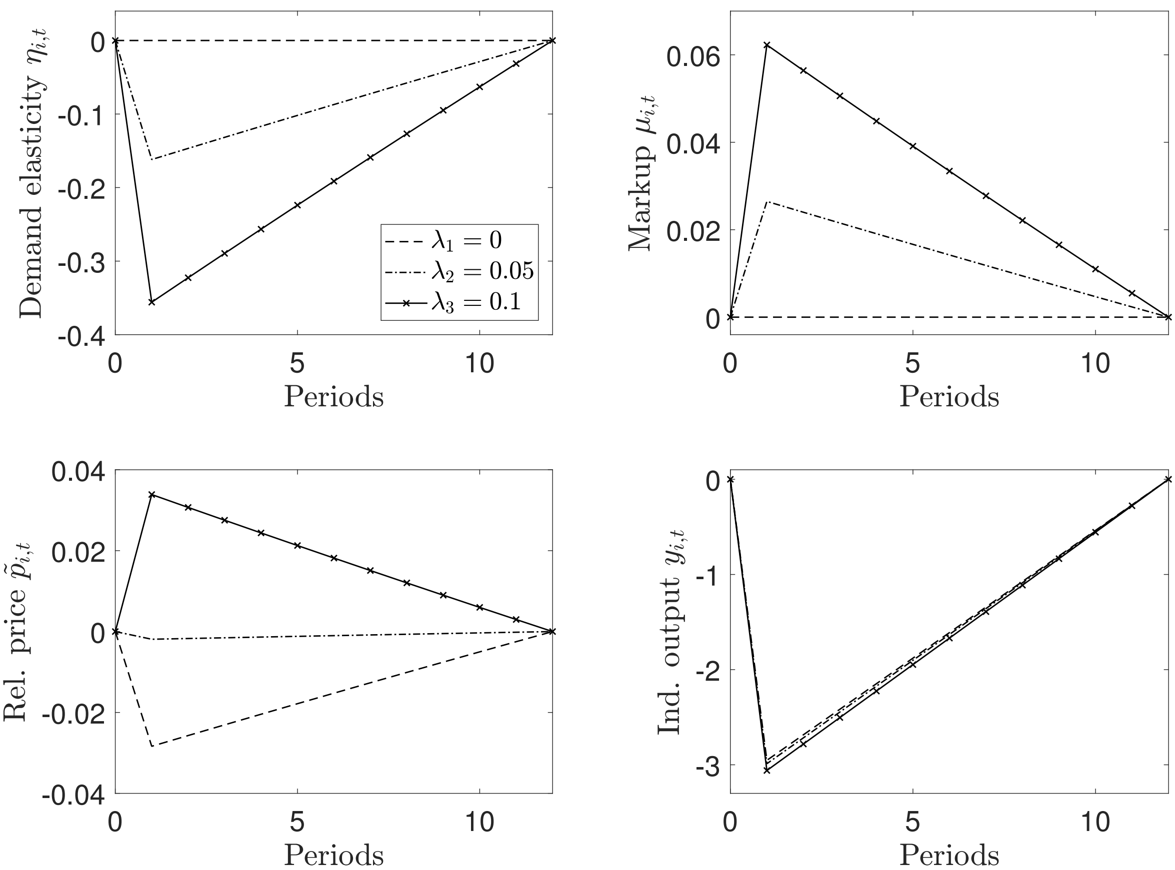



Figure 3.6: Effects of a decline in $A_t$ by 3% in period 1 with linear recovery until period 13. Changes in percent compared to period 0. $\lambda_1 = 0$ $\lambda_2 = 0.05$ and $\lambda_3 = 0.1$.

Figure 3.6 shows the relative changes of the demand elasticities, markups, relative

[6]As prices are fully flexible, this problem is static and no transitional effects occur. The time dimension is of illustrative purpose.

prices and output for individual goods with subsistence levels $\lambda_1$, $\lambda_2$ and $\lambda_3$. The relative changes refer to the percentage deviation from the equilibrium values in period 0. The reduction in aggregate productivity leads to a general decline in output and consumption of all individual goods. From equation 3.4 we know that a decline in $y_{i,t}$ reduces the demand elasticity for good i, which generates higher markups for firm i. However, this only holds if the subsistence level of good i is positive. The top graphs of Figure 3.6 show that for good type 1 with zero subsistence level, both the demand elasticity and the price markup are constant. In contrast, the demand elasticities for subsistence types 2 and 3 decrease and markups increase. The response to the decline in $A_t$ is more pronounced for goods with the highest level ob subsistence $\lambda_3$, which features the largest degree of necessity. Note that markups evolve countercyclically, which is also observed and discussed in Santos et al. (2022), Ravn et al. (2008) and Rotemberg and Woodford (1992).

Regarding the response of relative prices, we can observe that the relative price of goods with high subsistence level $\lambda_3$ increases, while the relative prices of the other two subsistence types decline. The decline in the relative price for good types with subsistence level of $\lambda_2$ is comparably small, whereas it is pronounced for type 1. The heterogeneous responses in relative prices are only possible, if the real wage declines more than aggregate TFP. This results in lower marginal costs, see equation 3.7.

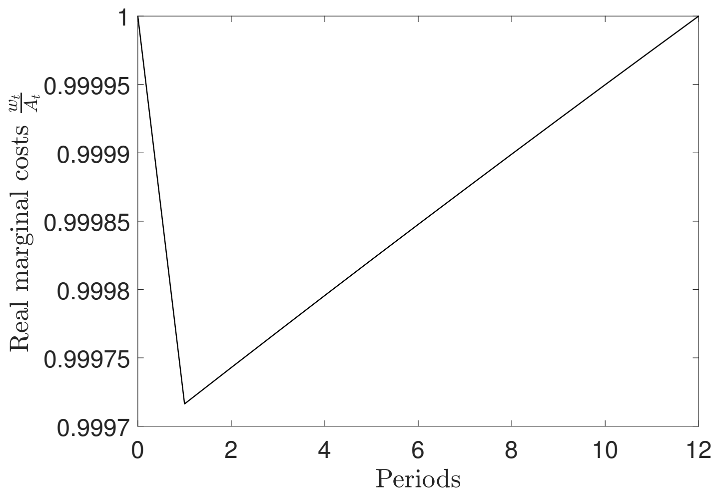



Figure 3.7: Percentage change of real marginal costs $\frac{w_t}{A_t}$ after a decline in A by 3% in period 1, relative to equilibrium in period 0. $\lambda_1 = 0$ $\lambda_2 = 0.05$ and $\lambda_3 = 0.1$.

Figure 3.7 shows that indeed marginal costs decline, as $A_t$ drops. This is the case, because individual output and therefore demand for labor declines. As can be seen in the lower right graph of Figure 3.6, the decline in individual output is greatest for consumer goods with subsistence type 3. Firms of type 3 face a low demand elasticity of their good and choose high relative prices, which leads to strong responses in demand for their goods. In line with the reduction in output, demand for labor declines. The reduction in labor demand together with the decline in the marginal product of labor from the drop in $A_t$ imply a lower real wage to maintain full employment.

For the specification of subsistence levels considered, only firms producing consumption goods with subsistence levels of type $\lambda_3$ feature an increase in markups that exceeds the decline in marginal costs. Thus they increase relative prices, while the other firms reduce them. Generally, relative prices of goods with zero subsistence levels decline, if at least for some consumption goods $\lambda_i > 0$ holds. Then marginal costs decline, while price markups for consumption goods with $\lambda_i = 0$ are constant.
For goods with positive levels of subsistence, the response of their relative prices depends on their degree of necessity relative to the rest of the economy. Figure 3.8 shows the responses to the decline in $A_t$ under a slight modification of subsistence values. Now $\lambda_3$ is set to 0.06 and $\lambda_1$ as well as $\lambda_2$ remain unchanged.
The lower $\lambda_3$ has qualitative implications for the relative price of goods type 2. As $\lambda_2$ is close to the maximum subsistence level now, the change in price markups is stronger than the decline in marginal costs for consumption goods of subsistence type 2.

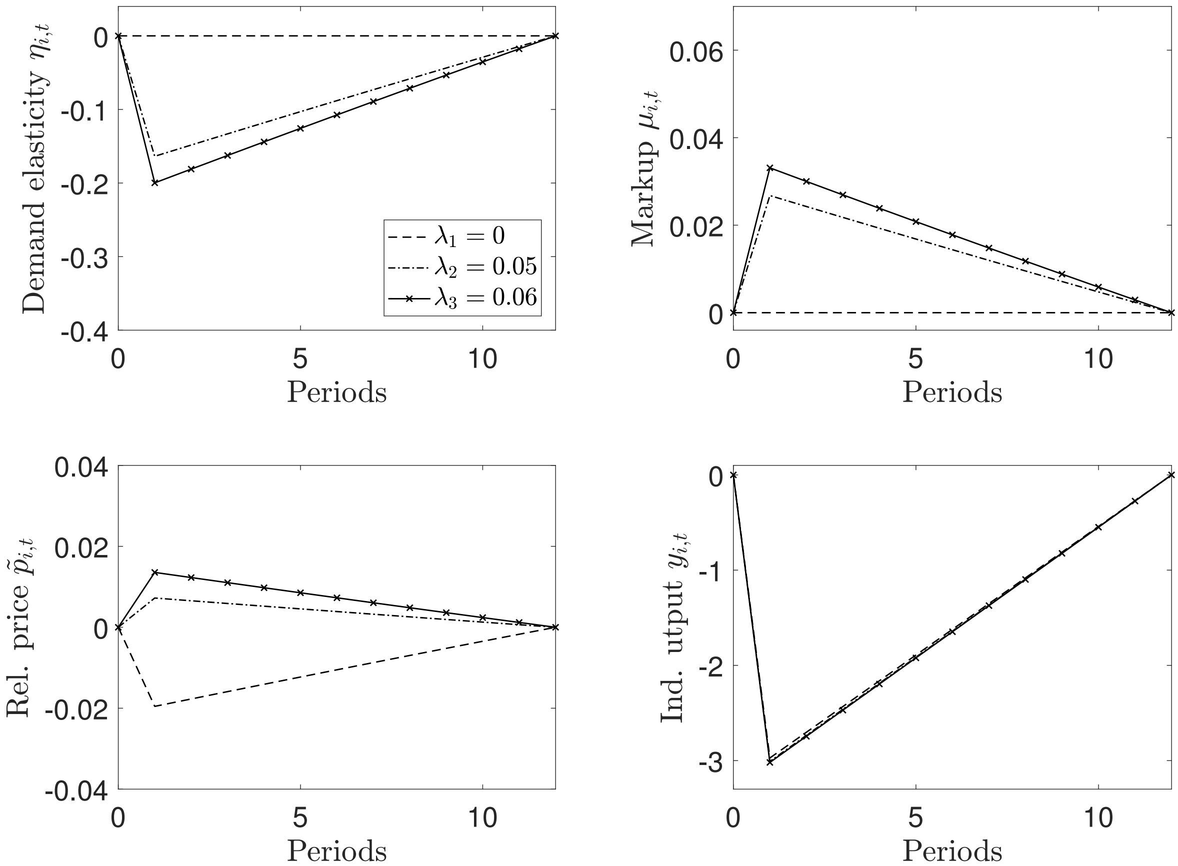



Figure 3.8: Effects of a decline in $A_t$ by 3% in period 1 in period 1 with linear recovery until period 13. Changes in percent compared to period 0. $\lambda_1 = 0$ $\lambda_2 = 0.05$ and $\lambda_3 = 0.06$.

## 3.6 Implications of price frictions

So far, I have shown that relative prices respond to an aggregate TFP shock heterogeneously, depending on the subsistence levels of the consumption goods. In this section, I introduce nominal price frictions à la Calvo (1983) into the model above in order to observe the resulting inflation rates at the individual goods level and at the aggregate level.

I extend the setup above by assuming that with a positive probability $\phi$ an individual firm cannot adjust its nominal price, while with probability $(1-\phi)$ nominal price adjustment is for free. Thus the Bellman equation of a price adjusting firm producing a good with subsistence level of consumption $\lambda_i$ in period t reads

$$V_{i,t}^{adj} = \max_{\tilde{p}_{i,t}} \left[ \tilde{p}_{i,t} y_{i,t} - w_t l_{i,t} + \beta \left( (1-\phi) V_{i,t+1}^{adj} + \phi V_{i,t+1}^{nadj} \left( \frac{\tilde{p}_{i,t}}{\Pi_{t+1}} \right) \right) \right]$$

subject to

$$\begin{aligned} y_{i,t} =& \tilde{p}_{i,t}^{-\epsilon} Y_t + \lambda_i, \\ l_{i,t} =& \frac{y_{i,t}}{A_t}, \\ \Pi_{t+1} =& \frac{P_{t+1}}{P_t}, \\ \tilde{p}_{i,t} =& \frac{P_{i,t}}{P_t}, \end{aligned}$$

where $V_{i,t}^{adj}$ is the sum of expected future profits discounted at factor $\beta$. Individual labor demand $l_{i,t}$ and demand for good $y_{i,t}$ are given by equations 3.5 and 3.6, respectively. $\Pi_t$ is the overall gross inflation rate between period t-1 and t. Total expected future profits of a firm that cannot adjust its nominal wage in period t are given by

$$V_{i,t}^{nadj} \left( \frac{\tilde{p}_{i,t-1}}{\Pi_t} \right) = \frac{\tilde{p}_{i,t-1}}{\Pi_t} y_{i,t} - w_t l_{i,t} + \beta \left( (1-\phi) V_{i,t+1}^{adj} + \phi_t V_{i,t+1}^{nadj} \left( \frac{\tilde{p}_{i,t-1}}{\Pi_t \Pi_{t+1}} \right) \right)$$

subject to equations 3.5 and 3.6.

Again, I assume that a negative TFP shock of the same size and transitory time path as in the previous section hits the model economy in period 1. In period 0, the economy is in the steady state with $A_0 = 1$ and the aggregate price level is normalized to 1, i.e.

$P_0 = 1$ with zero inflation.

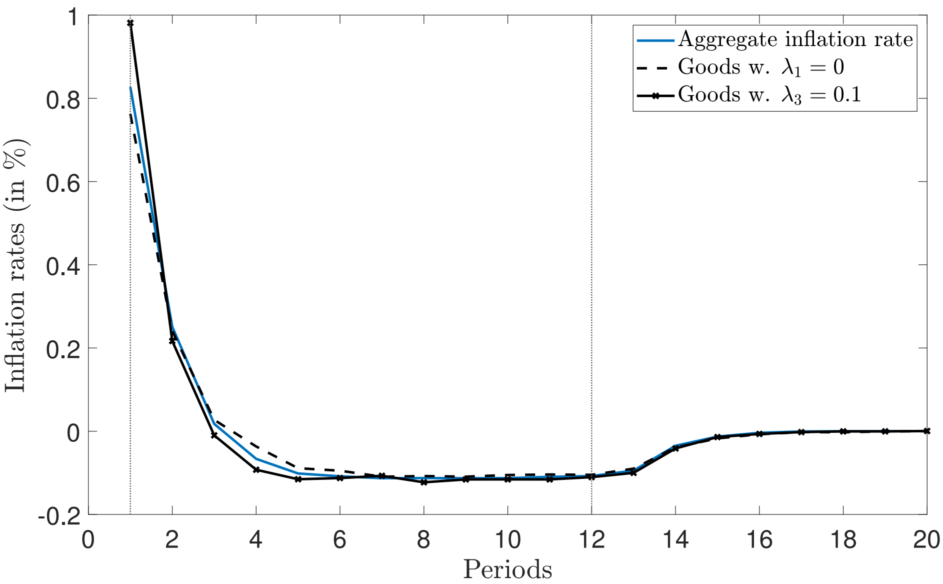



Figure 3.9: Net inflation rates in percent for consumption goods with different levels of subsistence and overall inflation.

Figure 3.9 shows the evolution of different inflation rates after the TFP shock. Aggregate inflation $\Pi_t$ is depicted in blue, where the values correspond to net inflation in percent. The other two rates of inflation correspond to price inflation of consumption goods with subsistence level $\lambda_1 = 0$ and $\lambda_3 = 0.1$.[7] The vertical dashed lines mark the first and the last period of the phase where $A_t$ is below 1.

Aggregate inflation is positive at around 0.8% in the shock period and declines, as $A_t$ moves back to its initial level. Inflation is negative from period 4 on, while aggregate TFP is still below 1. Nominal price changes for goods with subsistence types 1 and 3 follow this pattern. However, individual inflation rates differ from overall inflation.

For goods with the highest level ob subsistence $\lambda_3$, inflation exceeds aggregate inflation initially. As illustrated in the previous section, firms producing these goods increase their relative prices as a response to declined demand elasticities for their goods. For relative prices to increase, nominal prices of these goods must grow more strongly than the overall price level. The strong nominal price increases result in aggregate inflation. Note that the inflation rates shown include prices of firms that can not adjust

[7] The nominal price levels of goods with subsistence level $\lambda_i$ are determined using equation 3.2, where I only integrate over prices of goods with subsistence level $\lambda_i$. As I condition on a specific share of firms, I impose that the respective integrals are of unit mass.

their nominal prices. Thus inflation rates conditional on price adjusting firms would be stronger.

Price adjusting firms producing goods with subsistence levels of zero find it optimal to reduce their relative prices. They do so by choosing growth rates in nominal prices below the aggregate inflation rate.

From period 2 on, aggregate TFP moves back to the initial level and thus increases slightly. This means that firms of type 3, who can adjust prices in period 2, choose lower relative prices compared to the previous period. This is achieved by setting lower nominal prices, which is the source of declining inflation rates and deflation during the transition back to the original steady state.

Firms with lower subsistence levels in the demand for their goods want to slightly increase their relative prices again over time. As a result, prices of firms producing consumption goods with subsistence level $\lambda_1$ decline by less than the aggregate price level.

For illustrative reasons I omit the evolution of nominal prices for goods of subsistence type 2 here. We have seen in the flex price analysis that relative prices respond weakly to the aggregate TFP shock, as the opposite effects of declining marginal costs and increasing markups are of similar strengths. Under sticky prices the inflation rate of prices for these goods behave qualitatively as the prices for goods with subsistence type 1, but less strongly quantitatively. Price inflation for these goods is very close to aggregate inflation, see Figure 3.12 in the Appendix.

After $A_t$ reaches back to its initial level of 1 in period 13, all prices quickly converge back to their optimal long-run relative prices and remain there. Due to the imposed nominal price frictions, the steady state is reached. Roughly in period 18 most of the firms were able to adjust their prices and reach an equilibrium, where prices remain constant and net inflation becomes zero again.

Overall, the price responses of firms producing goods of subsistence type 3 overshoot the path of aggregate inflation. The model can thus replicate the empirically observed strong volatility of necessity goods.

## 3.7 Conclusion

In this work I show that the empirically observed variation of relative prices of different goods can be generated in a model with non-homothetic preferences and firm market

power.
Using CPI data, I show that consumption expenditure shares for different goods vary over the income distribution. The existence of necessity goods and luxury goods in household consumption baskets suggests that preferences are non-homothetic. Furthermore, I establish a stylized fact: Prices of necessity goods vary more strongly in inflation than prices of luxuries.
A model with a Dixit-Stiglitz consumption aggregator and subsistence levels of consumption for individual goods as well as monopolistic competition between firms links the two empirical observations: As a negative TFP shock hits the model economy, households reduce their consumption of all goods, bringing demand for individual items closer to their subsistence levels. This leads to lower price elasticity of demand, which increases price markups. For consumption goods with high levels of subsistence this effect is especially pronounced. Firms producing these goods increase their relative prices. In contrast relative prices of goods with comparably low degrees of necessity decline.
If price frictions are added to the model, inflation rates of goods with different levels of subsistence in their demand function can be computed. I show that inflation of consumption goods featuring high subsistence levels is an important driver of aggregate inflation and is stronger than general price inflation.
The model can be extended by adding inequality on the household side. Appendix 3.D shows a possible way to include heterogeneity in labor incomes. This extension can generate heterogeneity in perceived inflation rates across households. In addition, the effect of inequality on relative price changes and inflation rates on the goods level could be examined quantitatively.

# References to chapter 3

Adam, K. and H. Weber (2019a). "Optimal Trend Inflation". *American Economic Review* 109(2), pp. 702–737.

Aguiar, M. and M. Bils (2015). "Has Consumption Inequality Mirrored Income Inequality?" *American Economic Review* 105(9), pp. 2725–2756.

Amiti, M., O. Itskhoki, and J. Konings (2019). "International Shocks, Variable Markups, and Domestic Prices". *Review of Economic Studies* 86(6), pp. 2356–2402.

Aoki, K. (2001). “Optimal monetary policy responses to relative-price changes”. *Journal of Monetary Economics* 48(1), pp. 55–80.

Argente, D. and M. Lee (2021). “Cost of Living Inequality During the Great Recession”. *Journal of the European Economic Association* 19(2), pp. 913–952.

Arquié, A. and M. Thie (2023). “Energy, Inflation and Market Power: Excess Pass-Through in France”. *IMK Working Paper No. 220, Hans-Böckler-Stiftung, Institut für Makroökonomie und Konjunkturfoschung (IMK).*

Auclert, A. (2019). “Monetary Policy and the Redistribution Channel”. *American Economic Review* 109(6), pp. 2333–2367.

Auer, R., A. Burstein, S. Lein, and J. Vogel (2023). “Unequal Expenditure Switching: Evidence from Switzerland”. *Review of Economic Studies*, pp. 1–32.

Braun, R. and S. M. Lein (May 2020). “Heterogeneity in Inflation and Preferences across Households”. *Working Paper.*

Breyer, F. (2015). *Mikroökonomik*. Springer.

Calvo, G. A. (1983). “Staggered prices in a utility-maximizing framework”. *Journal of Monetary Economics* 12(3), pp. 383–398.

Cavallo, A. (2023). “Inflation with Covid Consumption Baskets”. *IMF Economic Review*, pp. 1–16.

Clayton, C., X. Jaravel, and A. Schaab (Jan. 2018). “Heterogeneous Price Rigidities and Monetary Policy”. *Available at SSRN 3186438.*

Coibion, O., Y. Gorodnichenko, L. Kueng, and J. Silvia (2017). “Innocent Bystanders? Monetary policy and inequality”. *Journal of Monetary Economics* 88, pp. 70–89.

Cravino, J., T. Lan, and A. A. Levchenko (2020). “Price stickiness along the income distribution and the effects of monetary policy”. *Journal of Monetary Economics* 110, pp. 19–32.

Fessler, P., F. Fritzer, and M. Salish (2023). “Who pays the price when prices rise?” *Monetary Policy & the Economy* Q4/22-Q1/23, pp. 67–84.

Fornaro, L. and M. Wolf (2023). “The scars of supply shocks: Implications for monetary policy”. *Journal of Monetary Economics* 140, S18–S36.

Guerrieri, V., G. Lorenzoni, L. Straub, and I. Werning (2021). “Monetary Policy in Times of Structural Reallocation”. *University of Chicago, Becker Friedman Institute for Economics Working Paper No. 2021-111.*

Hahn, V. and M. Marenčák (2020). “Price points and price dynamics”. *Journal of Monetary Economics* 115, pp. 127–144.

Handbury, J. (2021). “Are poor cities cheap for everyone? Non-homotheticity and the cost of living across US cities”. *Econometrica* 89(6), pp. 2679–2715.

Hochmuth, P., M. Pettersson, and C. J. Weissert (2023). “A Nonhomothetic Price Index and Cost-of-Living Inequality”. *Working Paper.*

Jaravel, X. (2021). “Inflation Inequality: Measurement, Causes, and Policy Implications”. *Annual Review of Economics* 13, pp. 599–629.

Kaplan, G. and S. Schulhofer-Wohl (2017). “Inflation at the household level”. *Journal of Monetary Economics* 91, pp. 19–38.

Kiss, R. and G. Strasser (Jan. 2024). “Inflation Heterogeneity Across Households”. *ECB Working Paper Series No. 2898.*

Lauper, C. and G. Mangiante (Apr. 2023). “Monetary Policy Shocks and Inflation Inequality”. *Available at SSRN 4409096.*

Lee, M. et al. (July 2022). “Do Black Households Face Higher and More Volatile Inflation?” *Richmond Fed Economic Brief No. 22-25.*

Meier, M. and T. Reinelt (2022). “Monetary Policy, Markup Dispersion, and Aggregate TFP”. *Review of Economics and Statistics*, pp. 1–45.

Nakamura, E. and J. Steinsson (2010). “Monetary Non-Neutrality in a Multisector Menu Cost Model”. *Quarterly Journal of Economics* 125(3), pp. 961–1013.

Nord, L. (Dec. 2023). “Shopping, Demand Composition, and Equilibrium Prices”. *Available at SSRN 4178271.*

Orchard, J. (Sept. 2022). “Cyclical Demand Shifts and Cost of Living Inequality”. *Available at SSRN 4033572.*

Ravn, M. O., S. Schmitt-Grohé, and M. Uribe (2008). “Macroeconomics of subsistence points”. *Macroeconomic Dynamics* 12(S1), pp. 136–147.

Rotemberg, J. J. and M. Woodford (1992). “Oligopolistic Pricing and the Effects of Aggregate Demand on Economic Activity”. *Journal of political Economy* 100(6), pp. 1153–1207.

Santos, C. D., L. F. Costa, and P. B. Brito (2022). “Demand, Supply and Markup Fluctuations”. *Economic Journal* 132(644), pp. 1620–1645.

Strasser, G., T. Messner, F. Rumler, and M. Ampudia (July 2023). “Inflation Heterogeneity at the Household Level”. *ECB Occasional Paper No. 2023/325.*

Tavares, F. (Jan. 2021). “Inflation heterogeneity and its impact on inequality: evidence from the United States”. *MPRA Paper No. 105461.*

Vermeulen, P., D. A. Dias, M. Dossche, E. Gautier, I. Hernando, R. Sabbatini, and H. Stahl (2012). "Price Setting in the Euro Area: Some Stylized Facts from Individual Producer Price Data". *Journal of Money, Credit and Banking* 44(8), pp. 1631–1650.

Wachter, J. A. and M. Yogo (2010). "Why Do Household Portfolio Shares Rise in Wealth?" *Review of Financial Studies* 23(11), pp. 3929–3965.

Wang, O. and I. Werning (2022). "Dynamic Oligopoly and Price Stickiness". *American Economic Review* 112(8), pp. 2815–2849.

# Appendix to chapter 3

## 3.A Additional graphs

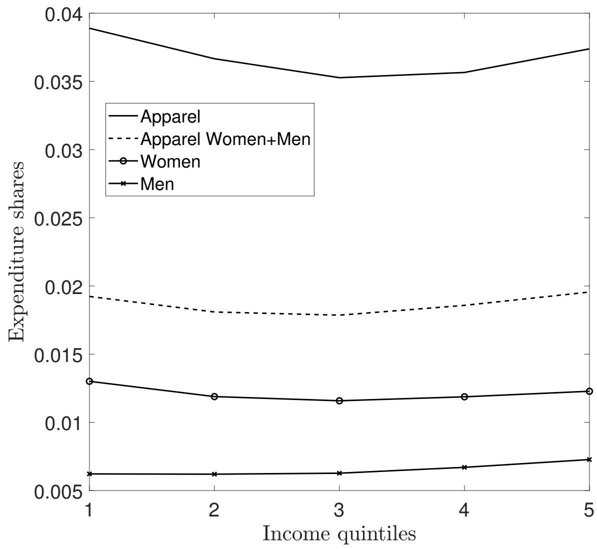



Figure 3.10: Expenditure shares for apparel (different categories) across the income distribution.

# 3.B A positive TFP shock

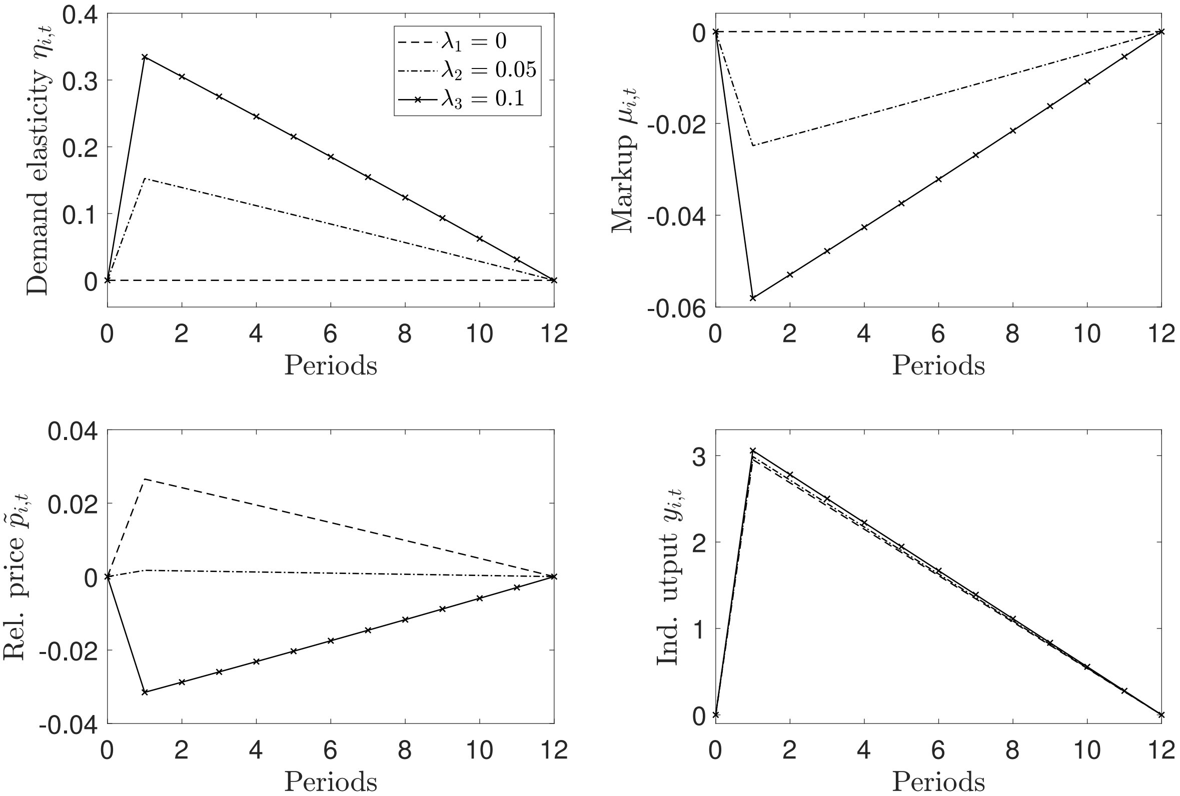



Figure 3.11: Effects of an increase in $A_t$ by 3% in period 1 in period 1 with linear recovery until period 13. Changes in percent compared to period 0. $\lambda_1 = 0$ $\lambda_2 = 0.05$ and $\lambda_3 = 0.1$.

# 3.C Inflation rates including $\lambda_2 = 0.05$

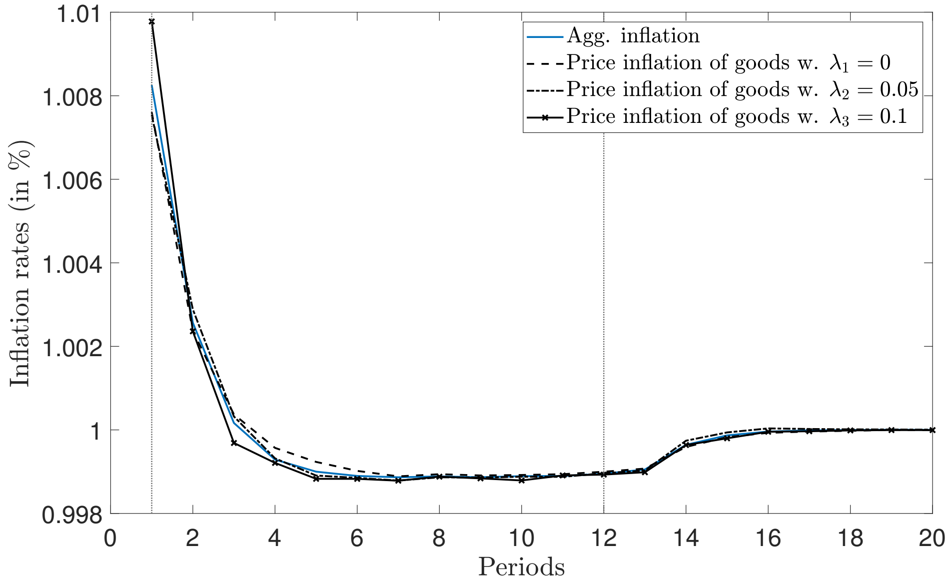



Figure 3.12: Net inflation rates in percent for consumption goods with different levels of subsistence and overall inflation, including $\lambda_2$.

# 3.D Potential model extension: Household inequality

So far, I have not included household inequality. In order to actually observe heterogeneity in perceived inflation among households, individuals have to differ, e.g. in their labor income.

As I assume heterogeneous levels of subsistence across goods, expenditure shares for specific goods vary across households with different levels of labor income. In particular, households with low incomes demand a larger fraction of goods with high $\lambda_i$ in their consumption bundle compared to high-income households.

We can consider a simple variation of the baseline model and assume that two types of households exist at equal weights. The types differ in their labor productivity $\alpha_1$ and $\alpha_2$, whereas the average labor productivity as well as individual labor supply are assumed to be equal to 1 and therefore aggregate labor supply is the same as in the model without household heterogeneity.

Individual household of type $h \in \{1, 2\}$ minimizes consumption expenditures subject to her individual consumption aggregator

$$C_{h,t} = \left( \int_0^1 (c_{h,i,t} - \lambda_i)^{\frac{\epsilon-1}{\epsilon}} \, di \right)^{\frac{\epsilon}{\epsilon-1}}. \tag{3.9}$$

The budget constraint states that total expenditures must not exceed the labor income of the household and real firm profits:

$$\int_0^1 p_{i,t} c_{h,i,t} di \leq W_t \alpha_h + P_t \int_0^1 \pi_{i,t}$$

The budget constrain in real terms can be stated as

$$C_{h,t} \leq w_t \alpha_h + \int_0^1 \pi_{i,t} - \int_0^1 p_{i,t} \lambda_i di.$$

If household $h$ is of low $\alpha$-type, it can afford a lower consumption basket and therefore the consumption level $C_{h,t}$ is lower than for a high $\alpha$-type household.

Individual demand of $h$ for $i$ is given by

$$c_{h,i,t} = \left(\frac{p_{i,t}}{P_t}\right)^{-\epsilon} C_{h,t} + \lambda_i. \tag{3.10}$$

Aggregate demand for good $i$ is given by the integral over individual demand for the specific good:

$$y_{i,t} = \int_0^1 c_{h,i,t} dh.$$

For low-income households of type $\alpha_1$, the inelastic share of individual consumption for good $i$ is larger than for high income households of type $\alpha_2$, because is holds that $C_{1,t} < C_{2,t}$.

Adding labor heterogeneity on the household side can generate two additional insights. First, inflation rates on the household level can be computed. Thus one could identify by how much low-income households are exposed to comparably strong price variations of necessity goods relative to high-income households. Furthermore, one could investigate the effects of varying levels of subsistence on individual inflation rates as well as aggregate inflation.
Second, the impact of household inequality on relative price choices can be examined. To do so, model outcomes under different spreads between $\alpha_1$ and $\alpha_2$ could be compared.

# Abgrenzung

Das erste Kapitel "*How Does Inflation Affect Different Age Groups?*" ist ein Projekt in Zusammenarbeit mit Volker Hahn (Universität Konstanz). Der Inhalt wurde gemeinschaftlich und zu gleichen Teilen verfasst.

Das zweite Kapitel "*House Price Inflation, Low Interest Rates and Housing Choice*" entstand in Zusammenarbeit mit Alexander Braun und Julia Braun, beide Mitglieder des Instituts für Versicherungswirtschaft an der Universität St.Gallen. Mein Beitrag an der Forschungsarbeit liegt bei einem Drittel.

Das dritte Kapitel "*Firm Market Power and Non-homothetic Preferences: Implications for Relative Prices*" habe ich eigenständig und ohne Zuhilfenahme anderer als der angegebenen Hilfsmittel erarbeitet.

# List of Figures

# List of Tables

# Overall bibliography


Abbritti, M., A. Consolo, and S. Weber (Dec. 2021). “Endogenous growth, downward wage rigidity and optimal inflation”. *ECB Working Paper Series No. 2635.*

Adam, K., E. Gautier, S. Santoro, and H. Weber (2022a). “The Case for a Positive Euro Area Inflation Target: Evidence from France, Germany and Italy”. *Journal of Monetary Economics* 132, pp. 140–153.

Adam, K., O. Pfäuti, and T. Reinelt (May 2022b). “Subjective Housing Price Expectations, Falling Natural Rates and the Optimal Inflation Target”. *CEPR Discussion Paper No. DP17187.*

Adam, K. and P. Tzamourani (2016). “Distributional consequences of asset price inflation in the Euro Area”. *European Economic Review* 89, pp. 172–192.

Adam, K. and H. Weber (2019a). “Optimal Trend Inflation”. *American Economic Review* 109(2), pp. 702–737.

Adam, K. and H. Weber (Sept. 2019b). “Price Trends over the Product Life Cycle and the Optimal Inflation Target”. *Bundesbank Discussion Paper 32/2019.*

Aguiar, M. and M. Bils (2015). “Has Consumption Inequality Mirrored Income Inequality?” *American Economic Review* 105(9), pp. 2725–2756.

Amano, R., K. Moran, S. Murchison, and A. Rennison (2009). “Trend Inflation, Wage and Price Rigidities, and Productivity Growth”. *Journal of Monetary Economics* 56(3), pp. 353–364.

Amiti, M., O. Itskhoki, and J. Konings (2019). “International Shocks, Variable Markups, and Domestic Prices”. *Review of Economic Studies* 86(6), pp. 2356–2402.

Aoki, K. (2001). “Optimal monetary policy responses to relative-price changes”. *Journal of Monetary Economics* 48(1), pp. 55–80.

Argente, D. and M. Lee (2021). “Cost of Living Inequality During the Great Recession”. *Journal of the European Economic Association* 19(2), pp. 913–952.

Arquié, A. and M. Thie (2023). “Energy, Inflation and Market Power: Excess Pass-Through in France”. *IMK Working Paper No. 220, Hans-Böckler-Stiftung, Institut für Makroökonomie und Konjunkturfoschung (IMK).*

Arundel, R. (2017). “Equity Inequity: Housing Wealth Inequality, Inter and Intra-generational Divergences, and the Rise of Private Landlordism”. *Housing, Theory and Society* 34(2), pp. 176–200.

Ascari, G., L. Phaneuf, and E. Sims (2018). “On the Welfare and Cyclical Implications of Moderate Trend Inflation”. *Journal of Monetary Economics* 99, pp. 56–71.

Ascari, G. and A. M. Sbordone (2014). “The Macroeconomics of Trend Inflation”. *Journal of Economic Literature* 52(3), pp. 679–739.

Auclert, A. (2019). “Monetary Policy and the Redistribution Channel”. *American Economic Review* 109(6), pp. 2333–2367.

Auclert, A., B. Bardóczy, and M. Rognlie (2023). "MPCs, MPEs, and Multipliers: A Trilemma for New Keynesian models". *Review of Economics and Statistics* 105(3), pp. 700–712.

Auer, R., A. Burstein, S. Lein, and J. Vogel (2023). "Unequal Expenditure Switching: Evidence from Switzerland". *Review of Economic Studies*, pp. 1–32.

Barczyk, D., S. Fahle, and M. Kredler (2023). "Save, Spend, or Give? A Model of Housing, Family Insurance, and Savings in Old Age". *Review of Economic Studies* 90(5), pp. 2116–2187.

Barro, R. and D. B. Gordon (1983). "A Positive Theory of Monetary Policy in a Natural Rate Model". *Journal of Political Economy* 91(4), pp. 589–610.

Bartscher, A. K., M. Kuhn, M. Schularick, and U. Steins (May 2020). "Modigliani Meets Minsky: Inequality, Debt, and Financial Fragility in America, 1950-2016". *CEPR Discussion Paper No. DP14667*.

Basu, S. and C. L. House (2016). "Allocative and Remitted Wages: New Facts and Challenges for Keynesian Models". In: *Handbook of Macroeconomics*. Vol. 2, pp. 297–354.

Bielecki, M., M. Brzoza-Brzezina, and M. Kolasa (2022). "Intergenerational Redistributive Effects of Monetary Policy". *Journal of the European Economic Association* 20(2), pp. 549–580.

Björklund, M., M. Carlsson, and O. Nordström Skans (2019). "Fixed-wage Contracts and Monetary Non-neutrality". *American Economic Journal: Macroeconomics* 11(2), pp. 171–92.

Blanco, A. (2021). "Optimal Inflation Target in an Economy with Menu Costs and a Zero Lower Bound". *American Economic Journal: Macroeconomics* 13(3), pp. 108–141.

Braun, R. and S. M. Lein (May 2020). "Heterogeneity in Inflation and Preferences across Households". *Working Paper*.

Braun, R. and S. M. Lein (2021). "Sources of Bias in Inflation Rates and Implications for Inflation Dynamics". *Journal of Money, Credit and Banking* 53(6), pp. 1553–1572.

Breyer, F. (2015). *Mikroökonomik*. Springer.

Broer, T., N.-J. Harbo Hansen, P. Krusell, and E. Öberg (2020). "The New Keynesian Transmission Mechanism: A Heterogeneous-Agent Perspective". *Review of Economic Studies* 87(1), pp. 77–101.

Calvo, G. A. (1983). "Staggered prices in a utility-maximizing framework". *Journal of Monetary Economics* 12(3), pp. 383–398.

Cavallo, A. (2023). "Inflation with Covid Consumption Baskets". *IMF Economic Review*, pp. 1–16.

Christiano, L. J., M. Eichenbaum, and C. L. Evans (2005). "Nominal Rigidities and the Dynamic Effects of a Shock to Monetary Policy". *Journal of Political Economy* 113(1), pp. 1–45.

Clayton, C., X. Jaravel, and A. Schaab (Jan. 2018). "Heterogeneous Price Rigidities and Monetary Policy". *Available at SSRN 3186438*.

Coibion, O., Y. Gorodnichenko, L. Kueng, and J. Silvia (2017). "Innocent Bystanders? Monetary policy and inequality". *Journal of Monetary Economics* 88, pp. 70–89.

Coibion, O., Y. Gorodnichenko, and J. Wieland (2012). "The Optimal Inflation Rate in New Keynesian Models: Should Central Banks Raise Their Inflation Targets in Light of the Zero Lower Bound?" *Review of Economic Studies* 79(4), pp. 1371–1406.

Cooley, T. and E. Henriksen (2018). "The demographic deficit". *Journal of Monetary Economics* 93, pp. 45–62.

Cravino, J., T. Lan, and A. A. Levchenko (2020). "Price stickiness along the income distribution and the effects of monetary policy". *Journal of Monetary Economics* 110, pp. 19–32.

Davis, M. A., A. Lehnert, and R. F. Martin (2008). "The Rent-price ratio for the aggregate stock of owner-occupied housing". *Review of Income and Wealth* 54(2), pp. 279–284.

Davis, M. A. and F. Ortalo-Magné (2011). "Household expenditures, wages, rents". *Review of Economic Dynamics* 14(2), pp. 248–261.

Diercks, A. M. (June 2017). "The Reader's Guide to Optimal Monetary Policy". *Available at SSRN 2989237*.

Dotsey, M., R. G. King, and A. L. Wolman (1999). "State-dependent Pricing and the General Equilibrium Dynamics of Money and Output". *Quarterly Journal of Economics* 114(2), pp. 655–690.

Druedahl, J. and T. H. Jørgensen (2017). "A general endogenous grid method for multi-dimensional models with non-convexities and constraints". *Journal of Economic Dynamics and Control* 74, pp. 87–107.

Eichenbaum, M., S. Rebelo, and A. Wong (2022). "State-Dependent Effects of Monetary Policy: The Refinancing Channel". *American Economic Review* 112(3), pp. 721–61.

Erceg, C. J., D. W. Henderson, and A. T. Levin (2000). "Optimal Monetary Policy with Staggered Wage and Price Contracts". *Journal of Monetary Economics* 46(2), pp. 281–313.

Fessler, P., F. Fritzer, and M. Salish (2023). "Who pays the price when prices rise?" *Monetary Policy & the Economy* Q4/22-Q1/23, pp. 67–84.

Fischer, M. and M. Z. Stamos (2013). "Optimal Life Cycle Portfolio Choice with Housing Market Cycles". *Review of Financial Studies* 26(9), pp. 2311–2352.

Fischer, S. (1981). "Towards an Understanding of the Costs of Inflation: II". *Carnegie-Rochester Conference Series on Public Policy*. Vol. 15, pp. 5–41.

Fornaro, L. and M. Wolf (2023). "The scars of supply shocks: Implications for monetary policy". *Journal of Monetary Economics* 140, S18–S36.

Gertler, M., C. Huckfeldt, and A. Trigari (2020). "Unemployment Fluctuations, Match Quality, and the Wage Cyclicality of New Hires". *Review of Economic Studies* 87(4), pp. 1876–1914.

Golosov, M. and R. E. J. Lucas (2007). "Menu Costs and Phillips Curves". *Journal of Political Economy* 115(2), pp. 171–199.

Gonzalez-Eiras, M. and D. Niepelt (2008). "The Future of Social Security". *Journal of Monetary Economics* 55(2), pp. 197–218.

Guerrieri, V., G. Lorenzoni, L. Straub, and I. Werning (2021). “Monetary Policy in Times of Structural Reallocation”. *University of Chicago, Becker Friedman Institute for Economics Working Paper No. 2021-111.*

Guvenen, F. and A. A. Smith (2014). “Inferring Labor Income Risk and Partial Insurance From Economic Choices”. *Econometrica* 82(6), pp. 2085–2129.

Hahn, V. (2022). “Price Dispersion and the Costs of Inflation”. *Journal of Money, Credit, and Banking* 54(2-3), pp. 459–491.

Hahn, V. and M. Marenčák (2020). “Price points and price dynamics”. *Journal of Monetary Economics* 115, pp. 127–144.

Handbury, J. (2021). “Are poor cities cheap for everyone? Non-homotheticity and the cost of living across US cities”. *Econometrica* 89(6), pp. 2679–2715.

Hansen, G. D. (1993). “The cyclical and secular behaviour of the labour input: Comparing efficiency units and hours worked”. *Journal of Applied Econometrics* 8(1), pp. 71–80.

Hochmuth, P., M. Pettersson, and C. J. Weissert (2023). “A Nonhomothetic Price Index and Cost-of-Living Inequality”. *Working Paper.*

İmrohoroğlu, A. and K. Zhao (2022). “Rising wealth inequality: Intergenerational links, entrepreneurship, and the decline in interest rate”. *Journal of Monetary Economics* 127, pp. 86–104.

Jaravel, X. (2021). “Inflation Inequality: Measurement, Causes, and Policy Implications”. *Annual Review of Economics* 13, pp. 599–629.

Kaplan, G. and S. Schulhofer-Wohl (2017). “Inflation at the household level”. *Journal of Monetary Economics* 91, pp. 19–38.

Kaplan, G., G. L. Violante, and J. Weidner (Apr. 2014). “The Wealthy Hand-to-Mouth”. *NBER Working Paper Series No. 20073.*

Kim, J. and F. J. Ruge-Murcia (2009). “How much inflation is necessary to grease the wheels?” *Journal of Monetary Economics* 56(3), pp. 365–377.

Kinnerud, K. (Feb. 2022). “The effects of monetary policy through housing and mortgage choices on aggregate demand”. *Working Paper.*

Kiss, R. and G. Strasser (Jan. 2024). “Inflation Heterogeneity Across Households”. *ECB Working Paper Series No. 2898.*

Kose, M. A. and F. Ohnsorge (May 2023). “Slowing Growth: More Than a Rough Patch”. *MPRA Paper No. 117327.*

Kudlyak, M. (2014). “The cyclicality of the user cost of labor”. *Journal of Monetary Economics* 68, pp. 53–67.

Kuhn, M., M. Schularick, and U. I. Steins (2020). “Income and Wealth Inequality in America, 1949–2016”. *Journal of Political Economy* 128(9), pp. 3469–3519.

Kydland, F. E. and E. C. Prescott (June 1977). “Rules Rather than Discretion: The Inconsistency of Optimal Plans”. *Journal of Political Economy* 85(3), pp. 473–492.

Lauper, C. and G. Mangiante (Apr. 2023). “Monetary Policy Shocks and Inflation Inequality”. *Available at SSRN 4409096.*

Lee, M. et al. (July 2022). “Do Black Households Face Higher and More Volatile Inflation?” *Richmond Fed Economic Brief No. 22-25.*

Lian, C., Y. Ma, and C. Wang (2019). "Low interest rates and risk-taking: Evidence from individual investment decisions". *Review of Financial Studies* 32(6), pp. 2107–2148.

Lisack, N., R. Sajedi, and G. Thwaites (2017). "Demographic Trends and the Real Interest Rate".

Lucas, R. E. (1981). "Discussion of: Stanley Fischer, "Towards an understanding of the costs of inflation: II"". *Carnegie-Rochester Conference Series on Public Policy.* Vol. 15, pp. 43–52.

Luengo-Prado, M. J. (2006). "Durables, nondurables, down payments and consumption excesses". *Journal of Monetary Economics* 53(7), pp. 1509–1539.

Meier, M. and T. Reinelt (2022). "Monetary Policy, Markup Dispersion, and Aggregate TFP". *Review of Economics and Statistics*, pp. 1–45.

Nakamura, E. and J. Steinsson (2008). "Five Facts about Prices: A Reevaluation of Menu Cost Models". *Quarterly Journal of Economics* 123(4), pp. 1415–1464.

Nakamura, E. and J. Steinsson (2010). "Monetary Non-Neutrality in a Multisector Menu Cost Model". *Quarterly Journal of Economics* 125(3), pp. 961–1013.

Nord, L. (Dec. 2023). "Shopping, Demand Composition, and Equilibrium Prices". *Available at SSRN 4178271.*

Orchard, J. (Sept. 2022). "Cyclical Demand Shifts and Cost of Living Inequality". *Available at SSRN 4033572.*

Pallotti, F., G. Paz-Pardo, J. Slacalek, O. Tristani, and G. L. Violante (Nov. 2023). "Who bears the costs of inflation? Euro area households and the 2021–2022 shock". *NBER Working Paper Series No. 31896.*

Paz-Pardo, G. (2024). "Homeownership and Portfolio Choice over the Generations". *American Economic Journal: Macroeconomics* 16(1), pp. 207–237.

Ravn, M. O., S. Schmitt-Grohé, and M. Uribe (2008). "Macroeconomics of subsistence points". *Macroeconomic Dynamics* 12(S1), pp. 136–147.

Riboni, A. and F. J. Ruge-Murcia (2010). "Monetary Policy by Committee: Consensus, Chairman Dominance, or Simple Majority?" *Quarterly Journal of Economics* 125(1), pp. 363–416.

Rotemberg, J. J. and M. Woodford (1992). "Oligopolistic Pricing and the Effects of Aggregate Demand on Economic Activity". *Journal of political Economy* 100(6), pp. 1153–1207.

Rotemberg, J. J. and M. Woodford (1997). "An Optimization-Based Econometric Model for the Evaluation of Monetary Policy". *NBER Macroeconomics Annual* 12, pp. 297–346.

Santos, C. D., L. F. Costa, and P. B. Brito (2022). "Demand, Supply and Markup Fluctuations". *Economic Journal* 132(644), pp. 1620–1645.

Schmitt-Grohé, S. and M. Uribe (2010). "The Optimal Rate of Inflation". In: *Handbook of Monetary Economics.* Ed. by S.-C. Kolm and J. M. Ythier. Vol. 3. Elsevier Science B.V., Amsterdam. Chap. 13, pp. 653–722.

Strasser, G., T. Messner, F. Rumler, and M. Ampudia (July 2023). "Inflation Heterogeneity at the Household Level". *ECB Occasional Paper No. 2023/325.*

Tavares, F. (Jan. 2021). "Inflation heterogeneity and its impact on inequality: evidence from the United States". *MPRA Paper No. 105461.*

Tobin, J. (1972). "Inflation and Unemployment". *American Economic Review*, pp. 1–18.

Vermeulen, P., D. A. Dias, M. Dossche, E. Gautier, I. Hernando, R. Sabbatini, and H. Stahl (2012). "Price Setting in the Euro Area: Some Stylized Facts from Individual Producer Price Data". *Journal of Money, Credit and Banking* 44(8), pp. 1631–1650.

Wachter, J. A. and M. Yogo (2010). "Why Do Household Portfolio Shares Rise in Wealth?" *Review of Financial Studies* 23(11), pp. 3929–3965.

Wang, O. and I. Werning (2022). "Dynamic Oligopoly and Price Stickiness". *American Economic Review* 112(8), pp. 2815–2849.

Webber, K. L. and R. Burns (2021). "Increases in Graduate Student Debt in the US: 2000 to 2016". *Research in Higher Education* 62(5), pp. 709–732.

Wong, A. (May 2019). "Refinancing and The Transmission of Monetary Policy to Consumption". *Working Paper.*

Xu, M., J. Alonso-García, M. Sherris, and A. W. Shao (2023). "Insuring longevity risk and long-term care: Bequest, housing and liquidity". *Insurance: Mathematics and Economics* 111, pp. 121–141.

Zhou, J. (2020). "Household stock market participation during the great financial crisis". *Quarterly Review of Economics and Finance* 75, pp. 265–275.