House Price Expectations and Inflation Expectations: Evidence from Survey Data*

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Abstract

We find that households tend to overweight house price expectations when forming their inflation expectations. The finding is robust across several specifications and two survey data sets for the United States. We also find that there is a significant effect of the cognitive abilities of households as more sophisticated households don't overweight house price inflation as much. We model this household behaviour in a two-sector New Keynesian model with an overweighted and a non-overweighted sector and analytically derive a welfare loss function consistent with the micro-foundations of the model. In this setup, we show that to gauge the correct interest rate response, the central bank needs to be aware that some sectors are overweighted and that movements in expected inflation in such sectors are important for monetary policy.

JEL classification: D10, E12, E31, E52, E58.

Keywords: Salience, Inflation Expectations, House Price Expectations, Monetary Policy.

1 Introduction

Expectations about the future course of the economy have come to play a pivotal role in macroeconomics. In this context, it has become increasingly important to understand how households form inflation expectations. For instance, Coibion et al. (2020) have found a significant role of households' priors and perceptions about inflation, their shopping experience, knowledge about monetary policy, cognitive abilities, and exposure to media coverage about the economy, as main factors influencing inflation expectations of individuals.

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Amidst cognitive and informational constraints, it has been observed that households rely on their personal experiences and frequently observed prices to form expectations about inflation. For example, Coibion and Gorodnichenko (2015) and D'Acunto et al. (2021) have found that gasoline and grocery prices respectively, play a major role in determining inflation expectations by virtue of being most frequently observed by consumers. Additionally, based on insights from psychology and memory research, and confirmed by studies observing household behaviour in economics, it has been found that people tend to focus more on extreme experiences and large changes. Bordalo et al. (2022) have found that contrasting, surprising, or prominent stimuli automatically drive the attention of the decision-maker and distract them from their original goals. This implies that individuals would focus disproportionately more on items for which extreme price changes have been observed, even if those items account for low weights in the official inflation measurement.

In this paper, we find a novel channel of salience through house price expectations. Using two sets of household survey data – Survey of Consumer Expectations (SCE) by the Federal Reserve Bank of New York (FRBNY) and the Survey of Consumers by the University of Michigan – we find that individuals overweight from house price expectations to their inflation expectations. To obtain this finding, we use instrumental variables to control for possible endogeneity through common factors and/or omitted variables. We also examine the role of cross-sectional heterogeneity. In this respect, we find that households with higher numeracy don't overweight house price inflation as much.

Subsequently, we model this household behaviour in a two-sector New Keynesian (NK) model with an overweighted and a non-overweighted sector, and analytically derive the welfare loss function using a second-order approximation to the representative household's utility. Relative to a standard two-sector NK framework, we find that this overweighting behaviour modifies the IS equation, while the NK Philips curve and central bank's loss function remain unchanged. We show that to gauge the correct interest rate response, it is imperative for the central bank to be aware that some sectors are overweighted by consumers and that movements in expected inflation in such sectors are important for monetary policy.

The motivation for examining the salience of house prices comes from the observation that house prices have increased dramatically in the years prior to 2007 and have also received extensive media attention, especially since the global financial crisis. The preoccupation of US households with housing markets has always been strong such that it has been noticed that "house price watching has become a national pastime" (Himmelberg et al., 2005, p.67). Houses are typically the largest asset in the household portfolio and are associated with significant wealth and collateral effects. A large majority of the population in the US are homeowners and there is high geographic mobility suggesting that house prices are closely watched.[1] It is also important to note that Consumer Price Index (CPI) only accounts for the consumption part of houses, that is, housing services through rents and imputed rents, and not houses as

[1] As per the US Census Bureau, the homeownership rate in the country stands at 66 percent in the year 2020 and an average person moves residences more than eleven times in their lifetime.

assets. This implies that there is no direct impact of house prices on inflation. But households, as non-specialists, may not be able to make the distinction between the asset aspect of house prices and the price of housing services. They may see house prices changing and gauge signals from that to form their inflation expectations. This could potentially lead to overweighting of house price expectations to overall inflation expectations.

Our work is closely related to previous studies examining the role of the salience of frequently observed prices and large price changes in driving inflation expectations. D'Acunto et al. (2021) use novel data on the combination of prices and quantities of non-durable consumption baskets of US households, matched with their inflation expectations at the time they go shopping. They find that inflation expectations are governed by the size and frequency of household-specific grocery price changes, instead of the representative bundle, irrespective of their share in expenditure. Infrequent shoppers who tend to observe larger changes across shopping trips respond more to grocery price changes, and larger price changes have a stronger effect on inflation expectations. Coibion and Gorodnichenko (2015) have confirmed the sensitivity of consumers' expectations to oil prices using the Michigan Survey of Consumers. They find that households' inflation expectations rose sharply between 2009 and 2011 explained by the rise in the price of oil at the same time, thereby preventing a decrease in the price level.

Yellen (2016) has also discussed the strong correlation between gasoline prices and the inflation expectations of households. Bruine de Bruin et al. (2011) have conducted two studies to examine how respondents taking part in national surveys form their inflation expectations in order to explain the heterogeneity between responses. The first part instructed participants to recall 'any' price change and in the second part to recall the 'largest' price change; in either of the cases, households reported recalling items for which price changes were perceived to be extreme and went on to report extreme inflation expectations. They found that participants had specific prices in mind while reporting their expectations in surveys and were biased towards items associated with more extreme perceived price changes.

Our work also relates to the impact of cross-sectional heterogeneity on inflation expectations. Ehrmann et al. (2018) find that households with pessimistic attitudes about their future incomes and purchases, or those experiencing financial difficulties are associated with a stronger upward bias in their inflation expectations. In addition to everyday changes that households observe, Malmendier and Nagel (2016) document that individuals overweight the inflation experienced during their lifetimes in the sense that people who have lived through high inflationary episodes have systematically higher inflation expectations.

Additionally, our work connects with the literature on house prices, house price expectations and inflation as well. Building on the role of experiences in shaping expectations, Kuchler and Zafar (2019), using survey data, find that individuals extrapolate from their personal experiences of local house price changes and volatility to country-wide house price inflation, and that this holds irrespective of the extent of usefulness of such personal experiences. Exploiting individual heterogeneity, they find that the extrapolation is stronger for less sophisticated individuals. Adam et al. (2022) show that households revise their house price expectations too sluggishly over time and their capital gain expectations have a positive relationship with the the price-to-rent ratio. Using geographically disaggregated local house price and survey data, Stroebel and Vavra (2019) establish a causal response of local retail prices to changes in local house prices driven by changes in retail markup, in areas of high homeownership rates. They find that the retail price sensitivity of homeowners decreases with an increase in house prices and firms use that opportunity to raise their markups, thereby delineating a new source of business cycle variation.

The model in our paper is related to prior work on two-sector NK models. These include, but are not limited to, Aoki (2001) with a flexible price sector and a sticky price sector, Erceg and Levin (2006), Barsky et al. (2007), Petrella et al. (2019) with durable and non-durable sectors, and Gali and Monacelli (2005) with a domestic and foreign sector for a small open economy.

The paper is structured as follows: Section 2 describes the accounting benchmark to determine the impact of house price inflation on (overall price) inflation, which is later used to check the presence of overweighting in the survey data. Section 3 describes the data. The empirical results are presented in Section 4. Section 5 presents the two-sector NK model taking into account the overweighting behaviour of households, and Section 6 concludes.

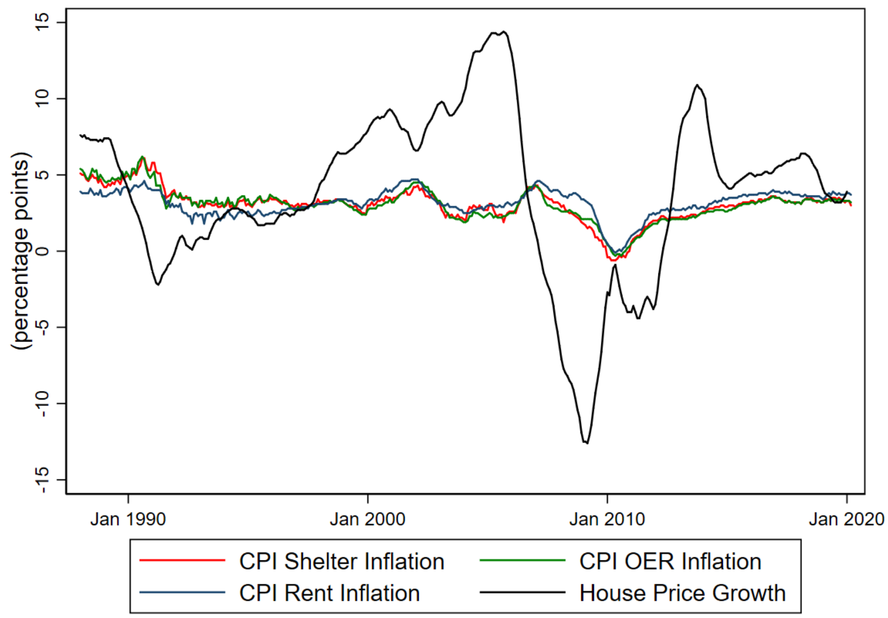
2 Estimating an accounting benchmark

In order to understand whether individuals are over or under-weighting from house price expectations to overall inflation expectations, we need to set a benchmark. This is on account of one key observation that actual house prices are not directly reflected in the CPI. Instead, CPI only reflects the consumption part of housing services relevant to the cost-of-living index. In the current practice in the United States, housing services are captured through the CPI component on 'shelter' which accounts for 32.706 percent weight in the index; shelter, in turn, has four sub-components, namely, rent of primary residence which accounts for 7.378 percent share, owner's equivalent rent (OER) which accounts for 24.043 percent, lodging away from home, and tenants and household insurance account which account for 0.925 and 0.360 percent, respectively.[2]

The OER component in CPI shelter is the imputed rent of owner-occupied housing. This represents the rent that homeowners implicitly pay to themselves to live in their home or the amount they could obtain by renting out their home. Since the majority of households in the US are homeowners, this component is very significant to keep a track of changes in housing 'services'. Over the last few decades, OER has been subject to various methodological changes: up to 1983, this used actual house prices to account for housing inflation, but that was abandoned as this reflected the asset aspect of housing, and not the consumption aspect

[2]Weights in overall CPI as on October 2022 (Source: Bureau of Labour Statistics).

Figure 1: House price growth and CPI shelter inflation



Notes: This figure shows CPI shelter inflation and the two sub-components of the same: CPI-rent and CPI-OER from the Bureau of Labour Statistics, US. House price growth is the growth rate of the S&P/Case-Shiller US national home price index. The sample period runs from 1987 to 2020.

needed for CPI. Starting in 1983, owners and renters were interviewed through housing surveys to get OER and rents information, respectively. However, since 1999, no homeowners are considered in the CPI housing survey sample, and a re-weighting of renters as per the share of homeowners in each region has been used to estimate OER. Over the period 1987 - 2020, there have been some large swings in house prices, while OER and other housing-related components of shelter have not kept up with these, as shown in Figure 1.[3] These large price changes could be salient to households and might distort their inflation expectations, while not being reflected in the CPI-related targets used by the central bank.

Table 1: Benchmark coefficients

Sample	Specification 1	Specification 2	Specification 3	Specification 4
1987–2019	0.01	0.02	-	0.01
1997–2019	0.03	0.02	0.02	0.01

Notes: The benchmark coefficients in this table are the product of regression coefficients from specifications 1 – 4 with the relative weight of the respective CPI component. The regression coefficients along with relative weights are shown in Table A.1 in Appendix A.1. Specification 3 for 1987-2019 is blank because the four components of CPI shelter, as in the current practice, came into effect from 1997 onwards.

To calculate the benchmark to get the impact of house price inflation on CPI inflation, we use linear regressions with house price growth as the independent variable and varied de-

[3] House price change is growth rate of SP/Case-Shiller U.S. National Home Price Index.

pendent variables under four specifications – CPI inflation, CPI shelter inflation, individual components of CPI shelter, and OER, respectively. These regressions are run for two different samples, namely 1987 to 2019 as well as 1999 to 2019 in order to be mindful of the methodological changes discussed previously. These regression coefficients are then weighted by the relative weight of the component in CPI over the respective sample. The estimated coefficients and relative weights are reported in Table A.1 in Appendix A.1. The product of these two gives the benchmark coefficients which are reported in Table 1. These benchmark coefficients represent the historical impact of house price growth on CPI inflation and its components, and we find that they lie in the range of 0.01 to 0.03.

3 Data description

We use two datasets which complement each other in terms of their sampling and survey methodologies, range of questions asked to households, and level of disaggregation of the survey. From these datasets, the focus of this study is on two questions: one-year-ahead inflation expectations and one-year-ahead house price expectations. In this section, we describe these two datasets and present summary statistics of the key variables.

3.1 Survey of Consumer Expectations

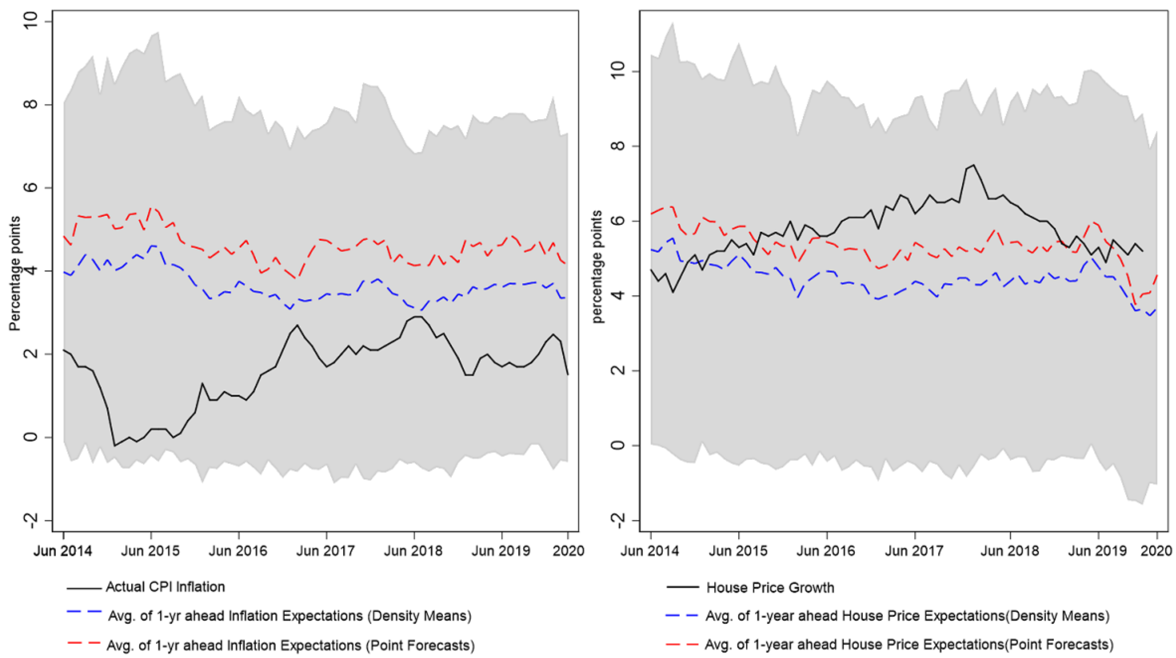
The first dataset we use is the Survey of Consumer Expectations (SCE) from the Federal Reserve Bank of New York (FRBNY). Launched in 2013, this is a nationally representative, an internet-based monthly survey of approximately 1300 household heads. It has a rotating panel structure where respondents remain in the sample for up to twelve consecutive months.

The quantitative part of the survey used for this analysis consists of three categories of questions: questions that elicit expectations of binary outcomes (such as the likelihood of the US house prices being higher in 12 months), questions that elicit pointwise expectations for continuous outcomes (such as the rate of inflation over the next 12 months), and questions that elicit respondents' probability densities for forecasts of continuous outcomes. The use of questions of the third type to get the subjective probability distribution for certain continuous outcomes is one of the innovations of the SCE.[4]

This dataset consists of about 76,000 observations over the period June 2013 to March 2019. While the basic questions regarding inflation and house price expectations are asked each time the individual takes the survey, some questions on individual-specific information are limited to repeat respondents. To be able to control for these individual characteristics, we exclude one-time respondents from the dataset and work with repeat respondents only. We rely on expectations from density means from questions of the third type, instead of point forecasts, although similar results hold with point forecasts as well. Figure 2 shows the actual inflation as well as house price growth in the US along with inflation and house

[4]For more details on this dataset, see Armantier et al. (2017).

Figure 2: SCE: (A) CPI inflation and inflation expectations and (B) Actual house price growth and house price expectations



Notes: The figure on the left shows the average one-year-ahead inflation expectations along with actual CPI inflation, and on the right shows one-year-ahead house price expectations along with actual house price growth. On both figures, survey expectations are reported for point forecasts (red dashed line) as well as density means (blue dashed line). The grey region is the cross-sectional one standard deviation interval for the respective inflation and house price expectations. Actual house price growth is SP/Case-Shiller US national home price index. The sample period runs from 2013 to 2019.

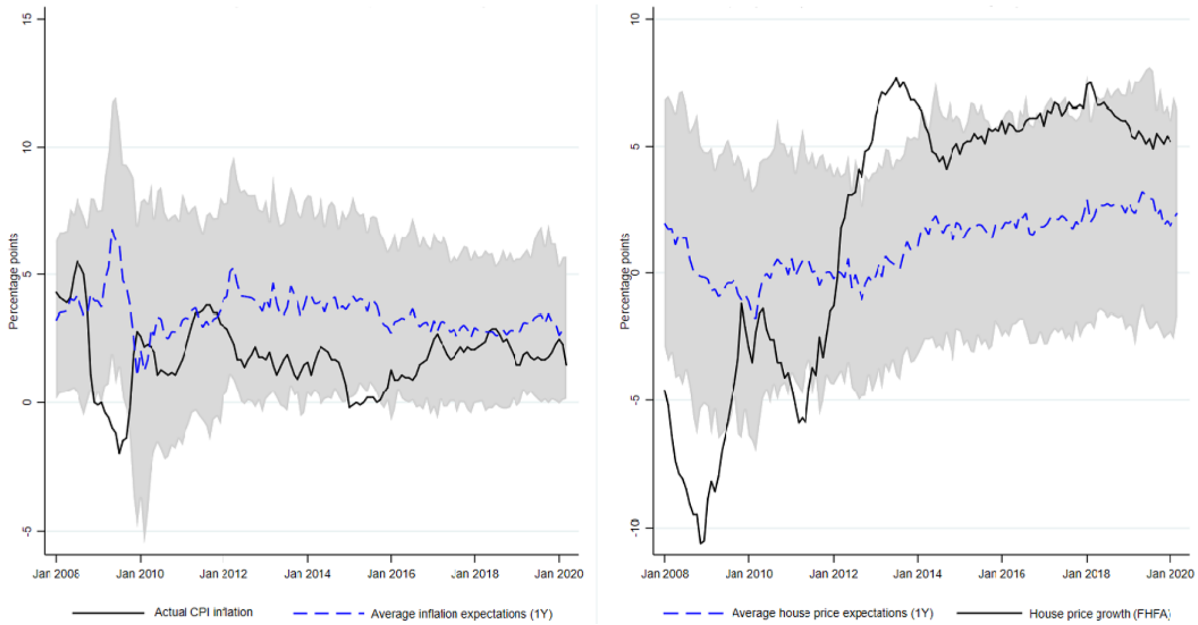
price expectations from this dataset. The grey-shaded area represents the cross-sectional one-standard deviation interval of inflation and house price expectations, respectively. The summary statistics of other variables from this dataset are presented in Appendix A.2.

3.2 Michigan Survey of Consumers

The second dataset we use is the Survey of Consumers (MSC) conducted by the Survey Research Center at the University of Michigan. This is a nationally representative survey and has been conducted since 1978. The data are available at a monthly frequency wherein each month about 500 interviews of US households are conducted. This survey also has a rotating panel component as each month about 40 percent of the households are those that were interviewed six months ago, and about 60 percent are first-time respondents.

While this is a much older survey than the SCE, house price expectations, unlike other expectations, are only available since 2007 and only for those respondents who are homeowners. Given this, our study covers the period from January 2007 to December 2019. The dataset is only accessible at the Census region level and further geographical dis-aggregation is not

Figure 3: MSC: (A) CPI and Inflation Expectations and (B) House Prices and House Price Expectations



Notes: The figure on the left shows the average one-year-ahead inflation expectations (blue dashed line) along with actual CPI inflation (black solid line), and on the right shows one-year-ahead house price expectations (blue dashed line) along with actual house price growth (black solid line). The grey region is the cross-sectional one standard deviation interval for the respective inflation and house price expectations. Actual house price growth is S&P/Case-Shiller US national home price index. The sample period runs from 2007 to 2019.

available. Figure 3 shows the actual inflation as well as house price growth in the US along with inflation and house price expectations from this dataset. The grey-shaded area represents the cross-sectional one-standard deviation interval of inflation and house price expectations, respectively. The summary statistics of other variables from this dataset are presented in Appendix A.2.

4 Empirical results

We seek to address the question: Do house price expectations influence overall inflation expectations more than what they should? We analyse this in a linear framework

$$\pi_{it}^{e} = \alpha + \beta\pi_{it}^{he} + \delta X_{it} + \gamma I_t + \epsilon_{it}, \tag{1}$$

where the dependent variable is the one-year-ahead inflation expectations for respondent i at time t, π_{it}^{he} is the one-year-ahead house price expectations for respondent i at time t, X_{it} are the individual characteristics such as demographics and other expectations, and I_t are the time fixed effects.

Although we control for time fixed effects, it is plausible that both house price expectations and inflation expectations could be driven by a third common factor that could lead the individual to revise both expectations or there could be an omitted variable bias from other CPI components. For this reason, we also present results using the Instrumental Variable approach.

We instrument house price expectations with the Wharton Residential Land Use Regulatory Index (WRLURI). This index is a measure of housing supply elasticity developed by Gyourko et al. (2008) and again updated by Gyourko et al. (2019) based on a national survey of local residential land use restrictions pertaining to housing or land use. This aggregate measure comprises eleven subindices that summarize information on different aspects of the regulatory environment. Higher values of this index indicate a stricter regulatory environment as housing supply could be expanded less easily in response to a demand shock. This in turn implies higher house prices in the region, and subsequently higher house price expectations, as found by Kuchler and Zafar (2019). We use WRLURI based on the second round of survey results completed in the year 2018 from Gyourko et al. (2019). These provide measures of regulation at the state level. The exclusion restriction requires that housing supply elasticity affects inflation expectations only through its impact on house price expectations.

WRLURI is time-invariant by design as regulations pertaining to land use are not changed very frequently. Even though this is not a drawback of this instrument, an approach in the literature has been to induce time-series variation through using its interaction with other relevant variables of interest, e.g. see Aladangady (2017). In our case, we compare results by also using the interaction of WRLURI with the 30-year fixed rate mortgage average in the US, since interest rates affect the user cost of housing and impact housing demand.[5]

Additionally, earlier work by Coibion and Gorodnichenko (2015) has found that gas and food prices influence households' inflation expectations. Therefore, it is imperative that we control for these expectations and also for possible endogeneity from the same. For gas price expectations, we use real gasoline taxes as the instrument. This has been used by Davis and Kilian (2011) and Coglianese et al. (2017) with the rationale that tax changes are typically implemented with a considerable lag making it unlikely that they are correlated with contemporaneous demand shocks. Additionally, Coglianese et al. (2017) has found that consumers may be more responsive to taxes than equal-sized changes in tax-inclusive gasoline prices because of perceived persistence and salience, and also given higher media coverage to the former. For food price expectations, we use the global price of food index as the instrument. This represents the benchmark prices of the global market which is determined by the largest exporter of a given commodity, so it would introduce exogeneity.

Another approach to control for endogeneity in the household survey literature is to use lagged survey data as instruments, for e.g. Bachmann et al. (2015). In the same spirit, we utilize the rotating panel nature of the datasets and use the six-month lagged interview data as the instrument for the current period observation. In one of the specifications we estimate in the next section, we have used these lagged observations along with other previously discussed

[5]The 30-year fixed mortgage rate used is the Freddie Mac, real 30-Year fixed-rate mortgage average in the United States.

instruments from the literature to estimate an over-identified model using Generalized Method of Moments (GMM).

4.1 Baseline results

The OLS and IV results from the SCE data are presented in Table 2. The first column shows the OLS results in the full sample; we find that a one-percentage-point increase in house price expectations increases inflation expectations of the households by 0.25 percentage-point. Comparing this with the benchmark coefficients in the range of 0.01 to 0.03, there is considerable evidence of overweighting from house price expectations to inflation expectations. The second column of Table 2 gives the OLS results for a smaller sample where only the last interview of each household has been used. The third column presents IV results for the same sample using lagged expectations from previous interviews as instruments, and Column 4 uses WRLURI index and other instruments to present the GMM results from an over-identified model. In all cases, IV coefficients are only marginally higher than the OLS coefficients and the first-stage F statistic passes the rule-of-thumb of F greater than 10. Across all specifications, demographics include age, income categories, education, gender, marital status, homeownership, race, years of living in a state. Time-fixed effects include time dummies for each survey month, and we control for state fixed effects as well. We also control for gas and food price expectations.[6]

The OLS and IV results from MSC data are presented in Table 3. Column (1) presents the OLS results and we find that a one-percentage-point increase in house price expectations increases inflation expectations of the households by 0.01 percentage-point. This is more in line with the benchmark. But when we correct for plausible endogeneity using the instruments, the coefficients are higher than the benchmark and more in line with the SCE results, as shown in column (2). This also holds true in the case of the GMM results from an over-identified model, as shown in column (3).[7] Thus, we find that once we control for the endogeneity, there is evidence of overweighting from house price expectations to inflation expectations on part of the households in the MSC data.

The Michigan data is available for the four Census regions, so region fixed effects have been added. A set of demographics to control for individual characteristics have been included as well which include age of the respondent, gender, marital status, income, household size, whether the respondent is a college graduate and whether the respondent is a high school graduate. Idiosyncratic expectations such as gas price expectations, interest rate expectations, expectations on the economic outlook, chances of increase in family income, durables and home buying attitudes, among others have also been controlled for.

[6] Table A.4 in Appendix A.3 presents the OLS results with and without controlling for gas and food price expectations. We find that the coefficient on house price expectations goes down to 0.25 from 0.294 when these controls are added.

[7] These results hold in the case of a smaller sample as well where we only use the first-time respondents.

Table 2: Baseline results using SCE

Inflation expectations (1Y)	(1) OLS-Full	(2) OLS	(3) IV - 2SLS	(4) IV - GMM
House price expectations (1Y)	0.250***	0.322***	0.471***	0.459***
	(0.011)	(0.025)	(0.062)	(0.056)
First stage F-stat:				
House price expectations (1Y)			77.72	42.96
Gas price expectations (1Y)			29.12	14.28
Food price expectations (1Y)			48.43	13.67
Demographics	Yes	Yes	Yes	Yes
Time Fixed Effects	Yes	Yes	Yes	Yes
State Fixed Effects	Yes	Yes	Yes	Yes
Other Expectations	Yes	Yes	Yes	Yes
R-squared	0.192	0.254	0.185	0.205
N	75574	6228	6127	5688

Notes: Column (1) has OLS results for the full sample. Column (2) has OLS results for the smaller sample of only the last observations for each household. Column (3) has IV-2SLS results using lagged expectations as instruments. Column (4) has IV-GMM results using lagged expectations and interaction of WRLURI with real mortgage rate, real global price of food index, real gasoline taxes as instruments. Standard errors in parentheses. *$p < 0.10$, **$p < 0.05$, ***$p < 0.01$.

Table 3: Baseline results using MSC

Price expectations (1Y)	(1) OLS	(2) IV-2SLS	(3) IV-GMM
House price expectations (1Y)	0.010**	0.183**	0.192*
	(0.005)	(0.093)	(0.104)
First stage F-stat:			
House price expectations (1Y)		41.57	23.93
Gas price expectations (1Y)		11.11	126.83
Over-identification test:			
Hansen J-statistic (Chi-sq p-value)			0.1673
Time fixed effects	Yes	Yes	Yes
Region fixed effects	Yes	No	No
Demographics	Yes	Yes	Yes
N	49292	44939	44626

Notes: Column (1) has OLS results for the full sample. Column (2) has IV-2SLS results using WRLURI and real gasoline taxes as instruments. Column (3) has IV-GMM results using WRLURI, the interaction of WRLURI with real mortgage rate, and real gasoline taxes as instruments. Standard errors are in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

4.2 Cross-sectional heterogeneity

In this section, we examine how respondent characteristics could explain differences in the extent of overweighting from house price expectations to overall inflation expectations of households. We examine the role of cognitive abilities captured through numeracy and education. The SCE includes a measure of respondents' numeracy, captured through questions

Table 4: By numeracy and education

Inflation expectations (1Y)	(1) Numeracy	(2) Education
High numeracy * House price expectations (1Y)	0.202***	
	(0.012)	
Low numeracy * House price expectations (1Y)	0.315***	
	(0.018)	
Graduate * House price expectations (1Y)		0.206***
		(0.013)
Not graduate * House price expectations (1Y)		0.282***
		(0.015)
Statistical Difference in Coefficients (Wald Test)	Yes	Yes
Demographics	Yes	Yes
Time Fixed Effects	Yes	Yes
State Fixed Effects	Yes	Yes
Other Expectations	Yes	Yes
R-squared	0.196	0.194
N	75574	75574

Notes: This uses the SCE data. Column (1) looks at the impact of numeracy. Participants who answer four out of five answers on numeracy correctly are classified as 'high numeracy'. Column (2) looks at the impact of the respondent having a minimum of a graduate degree. Standard errors are in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

on the basics of probability and compound interest. Participants who answer at least four of the five questions correctly are deemed to have high numeracy (Ben-David et al., 2018). The effect of education is captured through an individual being a graduate or higher versus not. In our sample, around seventy percent of individuals have a high numeracy score and fifty-five percent of individuals are graduates or higher. The analysis of the role of cognitive abilities reveals some interesting results, presented in Table 4.

We find that high numeracy individuals overweight less from house price expectations to inflation expectations compared to their low numeracy counterparts. We also find that the difference between the two categories is statistically significant. The same results hold for those who are graduates or higher, i.e. they overweight less from house price expectations to their overall inflation expectations. The difference between the two groups is statistically significant as well. These results make a lot of sense as we would expect less sophisticated individuals, i.e. those with relatively lower numeracy or education qualifications to be more influenced by the signals from salient prices.

More results from the examination of cross-sectional heterogeneity in the datasets are presented in Appendix A.4. The different characteristics considered include gender, age cohort experiences, homeownership, probability of moving to new residences, expected financial situation, etc.

5 Model

In this section, we present a two-sector closed economy New Keynesian model by extending the one-sector framework of Galí (2015). The model is a stylized framework representative of any two sectors, in which households focus more on one of the sectors relative to its true weight. In this respect, this part of the paper breaks new ground and applies more generally to the modelling and monetary policy implications of overweighting in any good, including the findings relative to gas prices and groceries in Coibion and Gorodnichenko (2015) and D'Acunto et al. (2021), respectively.

As such, the model has two non-durable sectors, and we abstract from the effects of durable goods. In addition to the reason mentioned above, including a durable sector would make the impact of overweighting per se difficult to single out. This is because previous work by Erceg and Levin (2006) has shown that durable sectors are more interest rate sensitive relative to non-durables, which introduces additional trade-offs for monetary policy. Moreover, Barsky et al. (2007) show that the durable goods sector matters disproportionately more for monetary policy. Given this, we abstract from the channel of durability and uncover the impact of overweighting in the simplest and more general framework. This modelling choice also offers the benefit of obtaining analytical results.[8]

Let O denote the overweighted sector which is more salient to the households and N denote the non-overweighted sector. This economy consists of three types of agents: a representative household, firms and the central bank. We assume that there is full labour mobility between the two sectors so that there is a uniform wage rate in the economy, and that there are no sectoral linkages in production.

5.1 Households

The representative infinitely-lived household chooses a composite consumption good C and supplies labour L to maximize the present discounted value of the expected utility function

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t U(C_t, L_t), \tag{2}$$

where $\beta \in (0,1)$ is the discount factor and

$$U(C_t, L_t) = \frac{C_t^{1-\sigma}}{1-\sigma} - \frac{L_t^{1+\phi}}{1+\phi}, \tag{3}$$

where σ is the inverse of inter-temporal elasticity of substitution and ϕ is the inverse of Frisch elasticity of labour supply. The household's aggregate consumption C_t depends on

[8] With this framework, we are able to show that overweighting has consequences for optimal monetary policy. Extending the results of the previous work by Erceg and Levin (2006) and Barsky et al. (2007) would likely mean that an overweighted durable sector would be even more significant.

consumption of the overweighted good $C_{O,t}$ and non-overweighted good $C_{N,t}$ according to a Cobb-Douglas technology given by

$$C_t \equiv \frac{(C_{N,t})^{1-\omega}(C_{O,t})^{\omega}}{\omega^{\omega}(1-\omega)^{1-\omega}}, \tag{4}$$

where $0 < \omega < 1$ is the share of the overweighted sector in total consumption. The sectoral consumption, C_j for $j = N, O$ is in turn a CES aggregate of quantities of the continuum of differentiated goods (of variety i) in the two sectors given by

$$C_{j,t} \equiv \left(\int_0^1 C_{j,t}(i)^{\frac{\varepsilon_j - 1}{\varepsilon_j}} di\right)^{\frac{\varepsilon_j}{\varepsilon_j - 1}}, \quad j = N, O,$$

where $\varepsilon_j > 1$ is the elasticity of substitution between the varieties within each sector.
The aggregate price index P_t is defined as

$$P_t = (P_{N,t})^{1-\omega}(P_{O,t})^{\omega}, \tag{5}$$

where $P_{N,t}$ is the price of the non-overweighted consumption good and $P_{O,t}$ is the price of the overweighted good consumed. Define relative price ratio, $S_t = \frac{P_{O,t}}{P_{N,t}}$, such that

$$P_t = P_{N,t}S_t^{\omega} = P_{O,t}S_t^{\omega-1}. \tag{6}$$

The sectoral price index is

$$P_{j,t} = \left(\int_0^1 P_{j,t}(i)^{1-\varepsilon_j} di\right)^{\frac{1}{1-\varepsilon_j}}, \quad j = N, O,$$

where $P_{j,t}(i)$ is the price charged by firm i in sector j for $j = N, O$. The household maximizes utility (3) subject to the intertemporal budget constraint

$$\int_0^1 P_{N,t}(i)\, C_{N,t}(i)\, di + \int_0^1 P_{O,t}(i)\, C_{O,t}(i)\, di + Q_t B_t \leq B_{t-1} + W_t L_t + T_t, \tag{7}$$

where W_t denotes the nominal wages, B_t are one-period bonds at price Q_t held by the household, T_t is a lump-sum component of income like dividends from ownership of firms. This also includes the solvency condition, $\lim_{T\to\infty} \mathbb{E}_t\{B_T\} \geq 0$.

In the empirical results, we find that the households overweight house prices when forming their inflation expectations. This has been observed in the existing literature for other types of goods as well, for instance, Coibion and Gorodnichenko (2015) find households focus disproportionately more on gas prices. This household behaviour of overweighting on one of the sectors in the aggregate price index would modify inflation expectations such that

$$\begin{aligned}\mathbb{E}_t\tilde{\pi}_{t+1} &= (1-\omega-\delta)\mathbb{E}_t\pi_{N,t+1} + (\omega+\delta)\mathbb{E}_t\pi_{O,t+1}, \\ &= \mathbb{E}_t\pi_{t+1} + \underbrace{\delta(\mathbb{E}_t\pi_{O,t+1} - \mathbb{E}_t\pi_{N,t+1})}_{\text{impact of overweighting}},\end{aligned} \tag{8}$$

where $\mathbb{E}_t\tilde{\pi}_{t+1}$ denotes the one-year-ahead inflation expectations of households at time t which are affected by overweighting, $\mathbb{E}_t\pi_{t+1}$ is the one-year-ahead inflation expectation at time t without any overweighting, and δ is the overweighting parameter. The above equation (8) shows that the overweighting behaviour distorts the inflation expectations of households by giving δ more weight to sector O in the overall CPI.

To incorporate this empirical observation in the model, the aggregate price index would be modified in periods t and $t+1$ to reflect the households' 'perceived' price index, relative to (5) as follows

$$\begin{aligned}\mathbb{E}_t\tilde{P}_{t+1} &= \mathbb{E}_t P_{N,t+1}^{1-\omega-\delta} P_{O,t+1}^{\omega+\delta}, \\ \tilde{P}_t &= P_{N,t}^{1-\omega-\delta} P_{O,t}^{\omega+\delta},\end{aligned} \tag{9}$$

where $\tilde{P}$ is the overweighted 'perceived' price index for the households.

From the household's optimisation problem, the Euler equation is

$$\beta Q_t^{-1}\mathbb{E}_t\left\{\left(\frac{C_{t+1}}{C_t}\right)^{-\sigma}\frac{\tilde{P}_t}{\tilde{P}_{t+1}}\right\} = 1. \tag{10}$$

Note that when $\delta = 0$, that is households are not focusing disproportionately on one sector, we are back to the original two-sector NK model without any overweighting.

5.2 Firms

On the production side, there are two distinct sectors in the economy which produce goods in sectors O and N. There is a continuum of firms, indexed by $i \in [0,1]$ within each sector $j = N, O$ which produce differentiated goods for consumption. Each firm faces a common production technology

$$Y_{j,t}(i) = A_{j,t}L_{j,t}(i),$$

where $Y_{j,t}(i)$ is the output of firm i in sector j, and $L_{j,t}(i)$ is the hours of labour employed by firm i in sector j. $A_{j,t}$ is the sector-specific productivity shock that follows an autoregressive process

$$a_{j,t} = \rho_{a_j} a_{j,t-1} + \varepsilon_{a_j,t},$$

where $a_{j,t} \equiv logA_{j,t}$ and $\varepsilon_{a_j,t} \sim i.i.d(0, \sigma_{a_j})$. Since labour is assumed to be fully mobile across the two sectors, there is a uniform wage rate in the economy. The nominal marginal cost for each firm in sectors $j = N, O$ is

$$MC_{j,t}^{n} = \frac{W_t}{MPL_{j,t}} = \frac{W_t}{A_{j,t}},$$

where $MPL_{j,t}$ is the marginal product of labour in sector j at time t.

The firms face identical sectoral demands taking aggregate price level P_t and consumption C_t as given. Following Calvo (1983), a firm in sector j resets its price with probability $(1 - \theta_j)$ in any given period and a fraction θ_j keeps their prices unchanged. Thus, the sectoral prices evolve according to

$$P_{j,t} = \left[\int_{s_j(t)}^{1} P_{j,t-1}^{1-\varepsilon_j}(i)\, di + (1 - \theta_j) \left(P_{j,t}^{*}\right)^{1-\varepsilon_j} \right]^{\frac{1}{1-\varepsilon_j}},$$

which simplifies to

$$P_{j,t} = \left[\theta_j P_{j,t-1}^{1-\varepsilon_j} + (1 - \theta_j) P_{j,t}^{*}\right]^{\frac{1}{1-\varepsilon_j}},$$

where $P_{j,t}^{*}$ is the common price chosen by the firms of sector j at time t and $s_j(t) \subset [0, 1]$ represents the set of firms not reoptimizing their posted price in period t. The firms which are able to update their prices choose price $P_{j,t}^{*}$ which maximises the expected present discounted value of future profits subject to a sequence of demand constraints for $k \geq 0$. That is,

$$\max_{P_{j,t}^{*}} \mathbb{E}_t \sum_{k=0}^{\infty} \theta_j^k Q_{t,t+k} \Pi_{j,t+k},$$

where $Q_{t,t+k}$ is the stochastic discount factor for nominal pay-offs between t and $t + k$, and $\Pi_{j,t+k} = P_{j,t}^{*} Y_{j,t+k} - TC_{j,t+k|t}^{n}(Y_{j,t+k})$ are the nominal profits for firms in sector j at time $t+k$ given that price chosen at t is being charged. $Y_{j,t+k}$ is the output in period k in sector j, and $TC^n(.)$ is the nominal total cost function.

Now, consider the case where the households' overweighting behaviour enters the firm's problem. This is important to see because Coibion and Gorodnichenko (2015) have explained that households' inflation expectations are a good proxy to the inflation expectations of firms. Hence it would be important to look at the impact of overweighting on the price-setting behaviour of firms. One way to incorporate household behaviour in the firm's problem is through the stochastic discount factor, $Q_{t,t+k} = \beta^k \left(\frac{C_{t,t+k}}{C_t}\right)^{-\sigma} \frac{\tilde{P}_t}{\tilde{P}_{t+k}}$, where $\tilde{P}$ would reflect the distorted price index. The first order condition which then maximizes the firm's profits and determines the price is:

$$\mathbb{E}_t \sum_{k=0}^{\infty} \theta_j^k \left[\beta^k \left(\frac{C_{t+k}}{C_t}\right)^{-\sigma} \frac{\tilde{P}_t}{\tilde{P}_{t+k}} \left(\frac{P_{j,t}^{*}}{P_{j,t+k}}\right)^{-\varepsilon_j} Y_{j,t+k} \left(P_{j,t}^{*} - \frac{\varepsilon_j}{1-\varepsilon_j} MC_{j,t+k|t}^{n}\right)\right] = 0, \qquad (11)$$

where $MC_{j,t+k|t}^{n}$ is the nominal marginal cost for a firm in sector j at time $t + k$ which last reset its price in t.

5.3 Equilibrium

We complete the non-policy part of the model by adding the dynamic IS equation and NK Phillips Curve. As standard in the literature, the Euler equation (10) can be log-linearised around a zero inflation steady state to determine the dynamic IS equation

$$\tilde{y}_t = \mathbb{E}_t \tilde{y}_{t+1} - \frac{1}{\sigma}\left(i_t - \mathbb{E}_t \tilde{\pi}_{t+1} - r_t^n\right), \tag{12}$$

where $\tilde{y}_t \equiv y_t - y_t^n$ is the (welfare relevant) output gap, y_t^n is the log of natural level of output, i_t is the nominal interest rate, and $r_t^n = \rho + \sigma \psi_{ya}^n \mathbb{E}_t a_{t+1}$ is the natural real interest rate with $\psi_{ya}^n = \frac{1+\phi}{\phi+\sigma}$.

To understand the impact of overweighting on the IS equation and how it differs from the standard framework, substitute equation (8) in (12) to get

$$\tilde{y}_t = \mathbb{E}_t \tilde{y}_{t+1} - \frac{1}{\sigma}\left(i_t - \mathbb{E}_t \pi_{t+1} - \underbrace{\delta(\mathbb{E}_t \pi_{O,t+1} - \mathbb{E}_t \pi_{N,t+1})}_{\text{impact of overweighting}} - r_t^n\right). \tag{13}$$

The real interest rate r_t is

$$r_t = i_t - \mathbb{E}_t \tilde{\pi}_{t+1}, \tag{14}$$

where the impact of overweighting is reflected through $\mathbb{E}_t \tilde{\pi}_{t+1}$ relative to $\mathbb{E}_t \pi_{t+1}$ in the standard NK framework.

To determine the dynamics of inflation in terms of the sectoral output gap and relative prices, we log-linearise the firm's optimal price setting equation (11) to get

$$p_{j,t}^* = (1 - \theta_j \beta) \sum_{k=0}^{\infty} \theta_j^k \beta^k \mathbb{E}_t \left[\hat{mc}_{j,t+k}^r + p_{j,t+k}\right]. \tag{15}$$

We show in Appendix A.6 that equation (15) is identical to the one derived without overweighting as the terms in $\tilde{p}$ drop out in equation (A.8). Hence, a change in the perceived price index does not alter the price-setting equation, which gives the standard sectoral Phillips curve even in the presence of overweighting. The sectoral Phillips curves are as follows:

$$\pi_{N,t} = \beta \mathbb{E}_t \pi_{N,t+1} + \chi_N \left((\sigma + \phi)\tilde{y}_{N,t} + (1 - \sigma - \phi)\omega \tilde{s}_t\right) + u_{N,t} \tag{16}$$

and

$$\pi_{O,t} = \beta \mathbb{E}_t \pi_{O,t+1} + \chi_O \left((\sigma + \phi)\tilde{y}_{O,t} + (\sigma + \phi - 1)(1 - \omega)\tilde{s}_t\right) + u_{O,t}, \tag{17}$$

where $\tilde{s}_t$ is the relative price ratio gap , $\chi_j = \frac{(1-\theta_j)(1-\beta\theta_j)}{\theta_j}$, and $u_{j,t}$ are the sector-specific cost-push shocks for $j = N, O$. The sectoral cost-push shocks for $j = N, O$ follow an exogenous

AR(1) process

$$u_{j,t} = \rho_{u_j} u_{j,t-1} + \varepsilon_{u_j,t}, \qquad \varepsilon_{u_j,t} \sim i.i.d(0, \sigma_{u_j}).$$

The aggregate NK Phillips curve in the economy is the sector-weighted aggregation of the sectoral Phillips curves (16) and (17)

$$\pi_t = (1-\omega)\pi_{N,t} + \omega\pi_{O,t}. \tag{18}$$

5.4 Welfare function

We derive the welfare function based on the micro-foundations of the model described in the previous section. Based on Woodford (2003) and Galí (2015), assuming that the monetary authority aims to maximise the welfare of the representative household, we obtain a second-order Taylor approximation of the representative consumer's lifetime utility when the economy remains in a neighbourhood of an efficient steady state. This gives the following loss function for the central bank

$$\begin{aligned} \frac{\mathcal{W}}{U_C' C} \approx -\frac{1}{2} E_0 \Sigma_{t=0}^{\infty} \beta^t \Big[& (1-\omega)\, \tilde{y}_{N,t}^2 + \omega \tilde{y}_{O,t}^2 + (\sigma + \phi - 1)\, \tilde{y}_t^2 \\ & + \frac{\varepsilon_N}{\chi_N} (1-\omega)\, \pi_{N,t}^2 + \frac{\varepsilon_O}{\chi_O} \omega \pi_{O,t}^2 \Big] + t.i.p + O \left\| \xi \right\|^3, \end{aligned} \tag{19}$$

where $t.i.p$ denotes the terms independent of policy and $O \left\| \xi \right\|^3$ includes terms of order higher than two. The welfare function balances the fluctuations in sectoral output gaps along with the variability in sectoral inflation rates.[9] Since (19) does not depend on δ, we find that the overweighting per se does not introduce an additional policy trade-off for the central bank.

Therefore, we find that the model with an overweighted sector differs from the standard two-sector framework with respect to the IS equation. The NK Phillips curve and the welfare function remain the same, even if firms in addition to households also display overweighting behaviour.

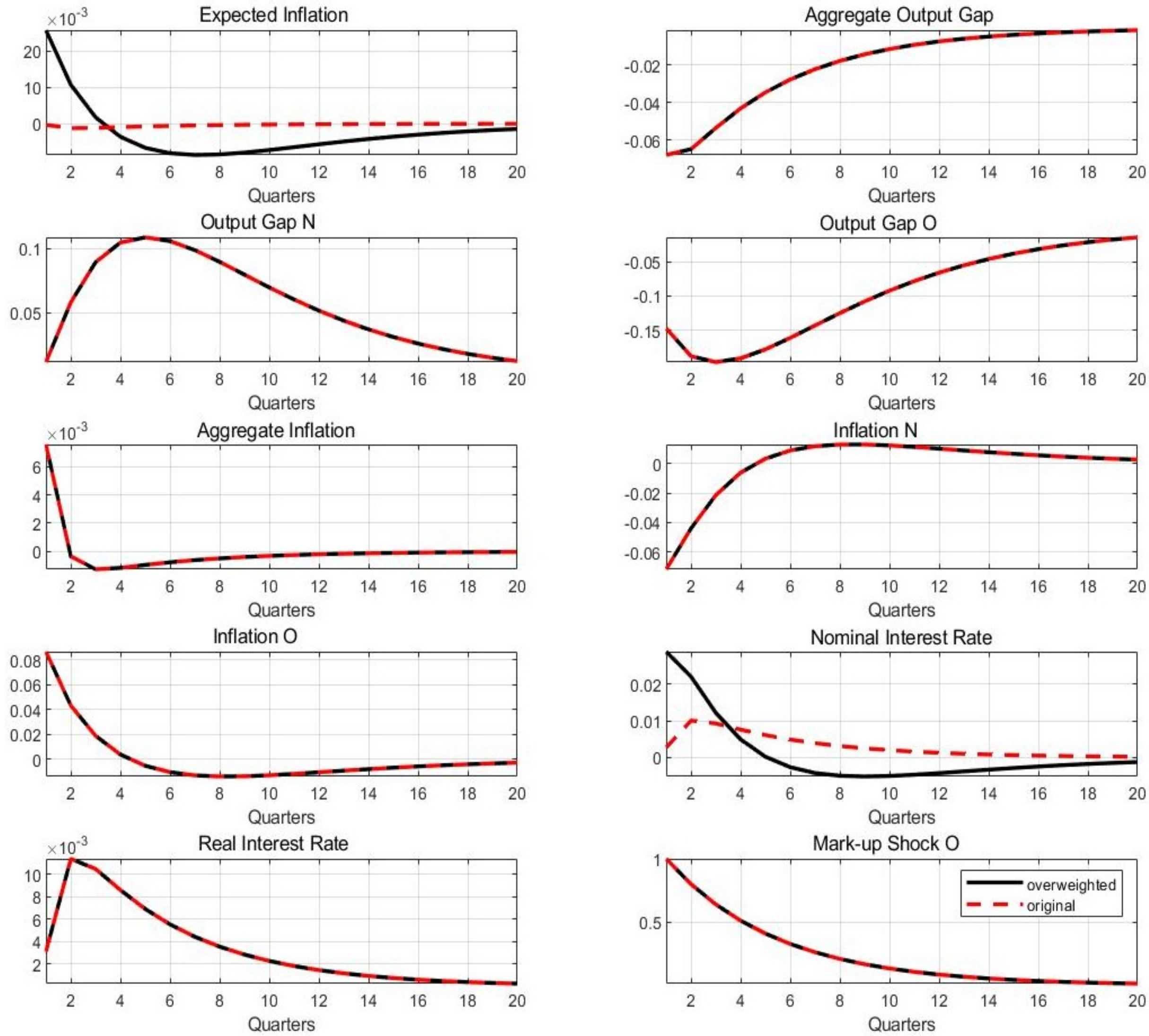
5.5 Ramsey policy

The optimal policy problem of the central bank is of minimising the welfare loss function (19) subject to the IS equation (13) and sectoral Philips curves (16) and (17). We examine the Ramsey policy response to a markup shock in the over-weighted sector in Figure 4 and compare it to the standard two-sector NK framework with no overweighting, i.e. $\delta = 0$. For this exercise, we assume the two sectors have equal weight and $\delta = 0.3$ in the overweighted model.

We see that in both the overweighted and the standard two-sector models, inflation in sector O increases and the output gap goes down in response to a markup shock. As sector

[9] Note that with $\omega = 1$, that is by putting all weight on a single sector, this loss function becomes identical to the standard one-sector loss function as in Galí (2015).

Figure 4: Optimal response to a persistent markup shock in sector O

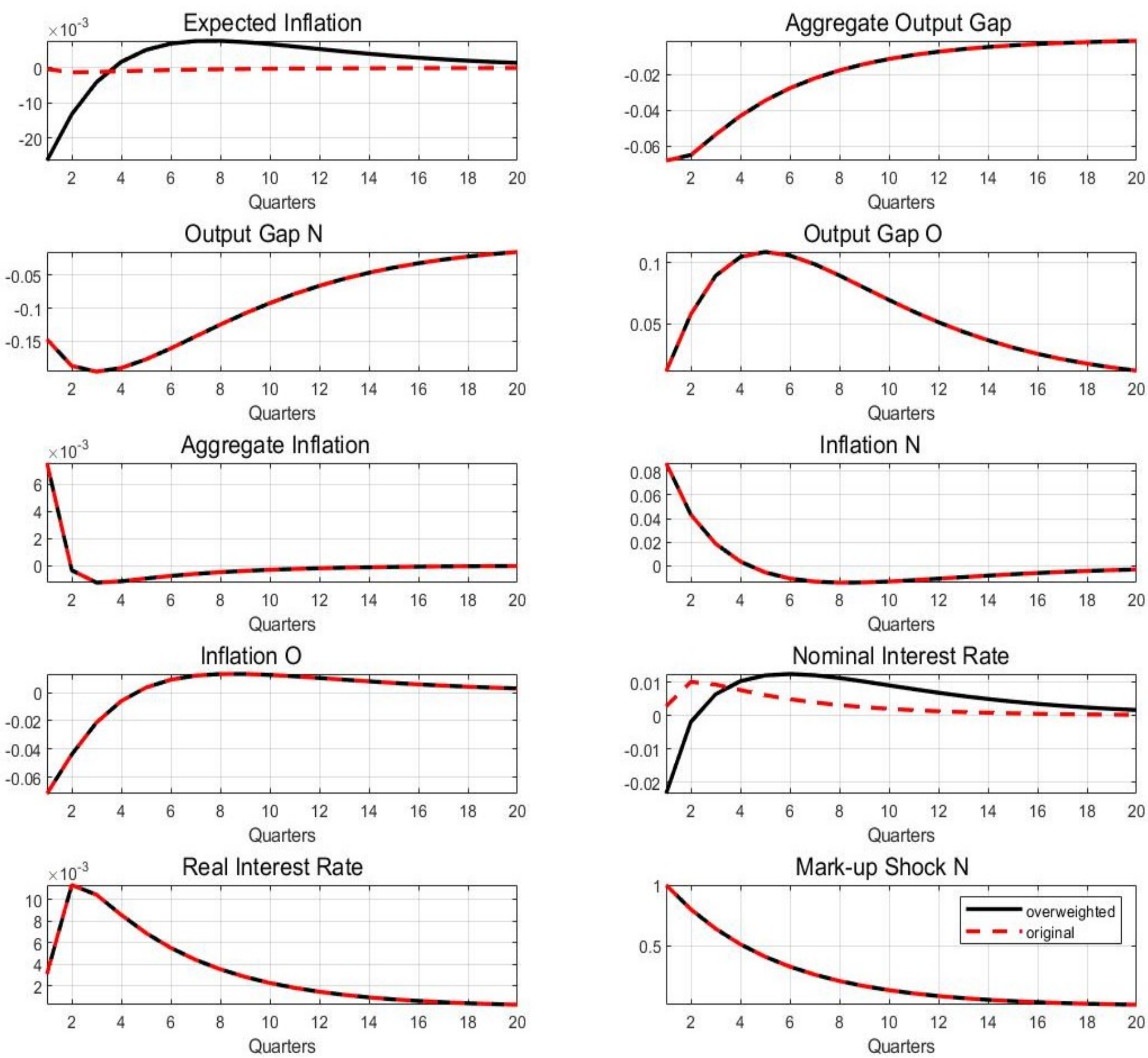


Notes: The figure shows the impulse responses of selected variables to a persistent one percent markup shock in the overweighted sector. All series are in percent deviations from their steady state except for the interest rate which is in absolute deviation from the steady state. The black line corresponds to the model which accounts for the overweighting while the red dashed line corresponds to the model with no overweighting.

O now produces less, wages fall and this makes inflation in sector N also go down. Overall the economy experiences higher inflation and a negative aggregate output gap. The optimal policy response of the central bank is to increase the nominal interest rate in line with expected inflation in both models. As expected inflation in the overweighted model is higher on account of a shock in sector O being overweighted by households, the nominal interest rate needs to be raised more strongly relative to the standard two-sector model. We see that the final allocations in the model with and without overweighting are the same, including the real interest rate. However, the policy instrument which is the nominal interest rate is different in the two models and needs to move in line with the respective expected inflation. The symmetric response to a markup shock in the non-overweighted sector N is in Figure 5.

This is the main result of this part of the paper. We show that it is important for the central bank to be aware that some sectors are overweighted by households in order to measure expected inflation correctly to gauge the correct response of the policy instrument.

Figure 5: Optimal response to a persistent markup shock in sector N



Notes: The figure shows the impulse responses of selected variables to a persistent one percent markup shock in the non-overweighted sector. All series are in percent deviations from their steady state except for the interest rate which is in absolute deviation from the steady state. The black line corresponds to the model which accounts for the overweighting while the red dashed line corresponds to the model with no overweighting.

6 Conclusion

Recent literature on salience has found that individuals focus disproportionately more on frequently observed prices and large price changes when forming their inflation expectations, even if those items account for low weight in official inflation measurement. The impact of gas and grocery prices in this regard has been well-established in the literature. In this paper, we find a novel channel through house prices. The motivation to look at house prices is that these are one of the larger price changes observed by households which are given substantial media attention, especially since the global financial crisis. High homeownership rates and geographic mobility in the United States also suggest that house prices are watched closely. Also, since houses are the biggest asset in a household's portfolio and are associated with significant wealth and collateral effects, there is a preoccupation among individuals with house prices.

Using two household survey data sets for the US, we examine the relationship between house price expectations and inflation expectations. We use the instrumental variable approach to control for possible endogeneity through common causes and/or omitted variable bias. We find that households tend to overweight their house price expectations when forming their inflation expectations. Furthermore, we find that there is a significant impact of the cognitive abilities of individuals in this behaviour as more sophisticated individuals overweight by a lesser degree.

Subsequently, we model this overweighting behaviour in a two-sector NK Model, with an overweighted sector and a non-overweighted sector. We find that the model with an overweighted sector differs from the standard two-sector framework with respect to the IS equation. The NK Phillips curve and the welfare function remain the same, even if firms in addition to households also display overweighting behaviour. In this model, overweighting per se does not introduce an additional policy-trade off for the central bank. Crucially, the nominal interest rate needs to be set differently; the central bank needs to realize that there is overweighting and measure inflation expectations correctly such that it sets the policy instrument appropriately.

This is a stylized model and can be representative of any two non-durable sectors that are captured in the CPI basket, such as grocery, gasoline or housing 'services', among others. Thus, these results extend to any sector(s) that is salient to households and we show that knowledge of such household behaviour has important monetary policy implications. It is important that the central bank is aware that some sectors are overweighted in consumers' inflation expectations. Once the central bank takes that into account, it is able to deliver the appropriate nominal interest rate.

In future research, we plan to make use of additional data sets to examine if there is overweighting of housing in inflation expectations in more countries. In this paper, we have kept the model as simple as possible in order to understand the direct implications of overweighting. As a next step, we will also analyze if additional trade-offs and interactions arise in more complex frameworks.

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Appendix

A.1 Benchmark Coefficients

We regress CPI and components of CPI which are relevant to housing on house price inflation to determine a benchmark. Four different specifications have been used, where the independent variable is house price growth and the dependent variable in the specification is (1) CPI inflation, (2) CPI shelter inflation, (3) components of CPI shelter inflation, and (4) owners equivalent rent of residences (OER) inflation (which captures the cost of owner-occupied housing), respectively. The regression coefficients from each specification are then weighted by the relative weight of the specific component in the CPI over two sample periods, 1987 to 2019 and 1997 to 2019. The relative weights and estimated coefficients are as in Table A.1. The product of the coefficient with the relative weight gives the benchmark coefficients which are reported in Table 1 in the main text.

Table A.1: Relative Weights of components of CPI and estimated coefficients

CPI component	CPI inflation		Shelter		Rent of primary residence	
Sample	Average weight	Coefficient	Average weight	Coefficient	Average weight	Coefficient
1987 – 2019	1	0.015 (0.017)	0.308	0.054*** (0.01)		
1997 – 2019	1	0.032** (0.017)	0.321	0.068*** (0.009)	0.067	0.036*** (0.009)

CPI component	Lodging away from home		Owners equivalent rent of residences		Tenants and HH's insurance	
Sample	Average weight	Coefficient	Average weight	Coefficient	Average weight	Coefficient
1987 – 2019			0.221	0.044*** (0.01)		
1987 – 2019	0.017	0.193*** (0.036)	0.223	0.053*** (0.008)	0.004	0.009 (0.014)

Notes: The independent variable is house price growth across all specifications. Specification (1) has CPI inflation as the dependent variable. In specification (2), the dependent variable is CPI shelter where the 'average weight' refers to the average share of shelter in the aggregate CPI index over the specified sample periods. For specification (3), each of the components of CPI shelter – rent of primary residence, lodging away from home, owners equivalent rent, and tenants and households insurance – are regressed on house price inflation, one at a time. The relative weight of each component in the CPI is reported in the above table. A weighted sum of these coefficients gives the benchmark coefficient in the main text. We only estimate the 1997-2019 sample period under this specification since the current practice of reporting these four components came into practice in 1997 only. In specification (4), the dependent variable is OER inflation. The results are robust to the inclusion of twelve leads and lags of the independent variable. Standard errors are in parentheses, $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$.

A.2 Summary statistics

For the FRBNY Survey of Consumer Expectations, the variables that we focus on are summarized below.

Table A.2: Summary statistics for SCE

Variable	Obs	Mean	Std. Dev.	Min	Max	P25	P50	P75
Inflation Exp.(1Y)(Point Forecast)	76071	4.41	6.17	-25	49	2	3	5
Inflation Exp.(1Y)(Density Mean)	75101	3.56	4.34	-25	36	1	3	6
House Price Exp. (1Y)(Point Forecast)	76071	5.19	5.98	-20	35	2	5	8
House Price Exp.(1Y)(Density Mean)	75342	4.33	5.06	-25	36	2	3	6
Food Price Expectation(1Y)	76071	5.97	5.29	-5	30	3	5	9
Gas Price Expectation(1Y)	76071	6.51	8.91	-15	50	2	5	10
Rent Expectation(1Y)	76071	7.42	6.83	-6	50	3	5	10
Graduate or Higher	75947	.57	.5	0	1	0	1	1
Gender	76070	.46	.5	0	1	0	0	1
Age	76046	51.01	15.07	18	99	38	52	63
Homeowner	76062	.74	.44	0	1	0	1	1
Married or living with someone	76071	.65	.48	0	1	0	1	1
Employed full-time	76071	.56	.5	0	1	0	1	1
Household Income(over 100K)	75313	.29	.45	0	1	0	0	1
Household Income(between 50 to 100K)	75313	.36	.48	0	1	0	0	1
HHincome(under 50k)	75313	.35	.48	0	1	0	0	1

For the Michigan Survey of Consumers, the summary statistics for the variables of interest and the demographics are as in Table (A.3).

Table A.3: Summary statistics for MSC

Variable	Obs	Mean	Std. Dev.	Min	Max	P25	P50	P75
Price expectations (1Y)	55602	3.43	3.81	-20	20	1	3	5
House price expectations (1Y)	55602	1.2	4.73	-20	20	0	0	3
Gas price expectations (1Y)	55602	5.9	9.43	-14.88	52.87	0	2.28	9.15
Durable buying attitudes	53718	.49	.86	-1	1	0	1	1
College graduate	55431	.59	.49	0	1	0	1	1
High school graduate	55494	.97	.16	0	1	1	1	1
Age	55291	55.05	15.7	18	97	44	56	66
Gender	55602	.45	.5	0	1	0	0	1
Marital status	55536	.7	.46	0	1	0	1	1
Family Size	55585	2.62	1.35	1	13	2	2	3
Region	55602	2.48	1.1	1	4	1	3	3
Total household income (current USD)	52785	102986	85255.55	2400	500000	50000	80000	127500
Market value of home	55602	851449.7	2244382	1000	9999998	140000	240000	400000

The average one-year-ahead inflation expectations are about 3.43 per cent while the average one-year-ahead house price expectations are 1.2 per cent. About 45 per cent of the respondents are females and close to 60 per cent of the sample is a college graduate while almost the entire sample has graduated high school. The full sample includes about 55,602 observations.

Other idiosyncratic expectations that have been controlled for in the results include: expected real family income (1-2 Years), chance of income increase (5 years) personal finances from a year ago, interest rate expectations (up/down) for next year, economy good/bad next year, economy good/bad next 5 years, unemployment more/less next year, the chance of job loss in 5 years, market value of home, expected home value (up/down), home buying attitudes, and home selling attitudes.

The twelve-month ahead gas price expectations in the interview look at the expected increase/decrease in gas prices in cents per gallon. The US All Grade Conventional Gas Price series has been used to convert this into one year ahead gas price expectations.

A.3 Additional regression results

A.3.1 Controlling for other expectations

Table A.4 presents the OLS results after controlling for gas and food price expectations using the SCE data. We find that the coefficient on house price expectations goes down to 0.25.

Table A.4: Controlling for other expectations: OLS

Inflation Expectations(1Y)	(1)	(2)	(3)
House Price	0.294***	0.259***	0.250***
Expectations(1Y)	(0.011)	(0.011)	(0.011)
Gas Price		0.046***	0.016***
Expectations(1Y)		(0.003)	(0.003)
Food Price			0.151***
Expectations(1Y)			(0.008)
Demographics	Yes	Yes	Yes
Time Fixed Effects	Yes	Yes	Yes
State Fixed Effects	Yes	Yes	Yes
Other Expectations	No	Yes	Yes
R-squared	0.144	0.173	0.192
N	75574	75574	75574

Notes: This uses SCE data. Column (1) has OLS coefficients for the impact of house price expectations on inflation expectations. Columns (2) and (3) control for gas price expectations, and gas as well as food price expectations, respectively. Standard errors in parentheses, * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Next, for the MSC data, we consider a smaller sample. We use the Wharton Index, the interaction of the Wharton Index with the 30-year real mortgage rate, and real gasoline taxes. In table A.5, the first column looks at the results for the first-time respondents only. In column (2), we use lagged gas price expectations in addition to the Wharton index and its interaction with the 30-year real mortgage rate as instruments. Since previous gas expectations are only available for households who enter the sample twice, the sample in this case, is smaller.

A.4 Cross-sectional heterogeneity

Table A.6 looks at the impact of homeownership on the relationship between house price expectations and inflation expectations. In column (1) of Table A.6, compared to homeowners, we find that renters overweight marginally more from house price expectations to overall inflation expectations. We also find that the difference between the two coefficients of homeowners and renters is statistically significant.

Next, we look at the joint impact of homeownership and the probability of moving to a new primary residence. The latter are those who reported 'more than 35% probability of

Table A.5: Baseline for repeat respondents

Price expectations (1Y)	(1)	(2)
House price expectations (1Y)	0.305**	0.223*
	(0.147)	(0.122)
First stage F-statistic:		
House price exp	15.01	
Gas price	69.96	
Over-identification test:		
Hansen J-statistic (Chi-sq p-value)	0.7512	0.7078
Time fixed effects	Yes	Yes
Region fixed effects	No	No
Demographics	Yes	Yes
Other expectations	No	No
N	28320	19991

Notes: This uses MSC data. Column (1) looks at repeat respondents only. Column (2) includes lagged gas price expectations for respondents who enter the sample twice. Standard errors are in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table A.6: By home ownership and probability of moving

Inflation Expectations (1Y)	(1) Home-ownership	(2) Moving
Homeowner * House price expectations (1Y)	0.235***	
	(0.012)	
Renter * House price expectations (1Y)	0.268***	
	(0.020)	
Homeowner * Plan to Move in 12months * House Price Expectations (1Y)		0.288***
		(0.024)
Renter * Plan to Move in 12months * House Price Expectations (1Y)		0.236***
		(0.029)
Renter * No Plan to Move in 12months * House Price Expectations (1Y)		0.298***
		(0.019)
Homeowner * No Plan to Move in 12months * House Price Expectations (1Y)		0.223***
		(0.012)
Statistical Difference in Coefficients (Wald Test)	Yes	Yes
R-squared	0.189	0.191
N	75574	75574

Notes: This uses the SCE data. Wald test 'Yes' denotes the statistically significant difference between homeowners and renters in column (1), and across all pairwise categories in column (2). Standard errors in parentheses, * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

moving to a new primary residence in next 12 months'. It is likely that those who report a likelihood of moving to a new residence would be observing house prices more keenly, which could explain the extent to which they overweight from house prices to inflation. In Table A.6, column (2) we find that homeowners who plan to move have slightly higher coefficients, while the opposite holds for renters. We also find that the difference between the two coefficients for both groups is statistically significant.

Subsequently, we split the sample between homeowners and renters to look at the impact of the expected financial situation in the next twelve months to be 'better, worse, same' in columns (1) and (2) of Table A.7.

Table A.7: Cross-sectional heterogeneity: Expected financial situation and probability of default for homeowners and renters

Inflation Expectations(1Y)	(1) Homeowners	(2) Renters	(3) Homeowners	(4) Renters
Situation(Better)* House Price Expectation	0.222***	0.272***		
	(0.017)	(0.024)		
Situation(Same)* Price Expectation	0.260***	0.322***		
	(0.015)	(0.025)		
Situation(Worse)* House Price Expectation	0.227***	0.213***		
	(0.024)	(0.065)		
Default*House Price Expectation			0.280***	0.308***
			(0.022)	(0.028)
No Default*House Price Expectation			0.228***	0.268***
			(0.013)	(0.023)
Statistical Difference in Coefficients (Wald Test)	Yes	Yes	Yes	No
Demographics	Yes	Yes	Yes	Yes
Time Fixed Effects	Yes	Yes	Yes	Yes
State Fixed Effects	Yes	Yes	Yes	Yes
Other Expectations	Yes	Yes	Yes	Yes
R-squared	0.198	0.207	0.189	0.202
N	55465	18800	55371	18746

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

We also look at the impact of the likelihood of default i.e. not being able to make one of the debt payments (that is, the minimum required payments on credit and retail cards, auto loans, student loans, mortgages, or any other debt) in columns (3) and (4) of Table A.7. We find that there is a statistically significant difference between the extent of overweighting based on homeownership, except for the likelihood of default in the case of renters.

Looking at the impact of gender and age-cohorts in Table A.8, we find that females overweight from house prices more than males. Also, those in the age group of over 60 overweight the least.

Table A.8: By gender and age

Inflation Expectations (1Y)	(1) Gender	(2) Age
Male * House Price Expectations (1Y)	0.205***	
	(0.017)	
Female * House Price Expectations(1Y)	0.282***	
	(0.013)	
Age (Over 60) * House Price Expectations (1Y)		0.224***
		(0.016)
Age (40 to 60) * House Price Expectations (1Y)		0.266***
		(0.017)
Age (Under 40)* House Price Expectations (1Y)		0.263***
		(0.019)
Statistical Difference in Coefficients (Wald Test)	Yes	Yes
Demographics	Yes	Yes
Time Fixed Effects	Yes	Yes
State Fixed Effects	Yes	Yes
Other Expectations	Yes	Yes
R-squared	0.194	0.192
N	75574	75574

Notes: This uses the SCE data. Wald test denotes the statistical difference between middle-aged and old in column (2). Standard errors in parentheses, * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table A.9 distinguishes between the respondents on the basis of their attitudes towards the housing market. The Michigan Survey of Consumers asks the respondents whether they think it is a good time to buy a house and similarly, whether it is a good time to sell a house. The responses are qualitative: good, bad or the same. We find that the house price expectations for those who think it is a good time to buy are statistically significant. Similarly, the house price expectations of those who think it is a good time to sell are statistically significant.

Table A.9: Home buying and selling attitudes

Price expectations	(1)	(2)
Home price expectations * Good	0.289**	
Home buying conditions	(0.137)	
Home price expectations * Bad	-0.037	
Home buying conditions	(0.182)	
Home price expectations * Same	-0.290	
Home buying conditions	(1.503)	
Home price expectations * Good		0.294**
Home selling conditions		(0.123)
Home price expectations * Bad		0.083
Home selling conditions		(0.227)
Home price expectations * Same		0.282
Home selling conditions		(0.857)
Over-identification test:		
Hansen J-statistic (Chi-sq p-value)	0.4285	0.4664
Time fixed effects	Yes	Yes
Region fixed effects	No	No
Demographics	Yes	Yes
N	19991	19991

Notes: This uses MSC data. Standard errors are in parentheses, * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

A.5 Derivation of the IS equation

Log-linearizing the Euler equation (10) after imposing market clearing condition $y_t = c_t$ gives

$$y_t = \mathbb{E}_t y_{t+1} - \frac{1}{\sigma}\left(i_t - \mathbb{E}_t \tilde{\pi}_{t+1} - \rho\right). \tag{A.1}$$

Substituting the real interest rate $r_t = i_t - \mathbb{E}_t \tilde{\pi}_{t+1}$ in the above

$$y_t = \mathbb{E}_t y_{t+1} - \frac{1}{\sigma}\left(r_t - \rho\right). \tag{A.2}$$

Equation (A.2) in the case of natural output is

$$y_t^n = \mathbb{E}_t y_{t+1}^n - \frac{1}{\sigma}\left(r_t^n - \rho\right). \tag{A.3}$$

Subtracting $(A.3)$ from $(A.2)$

$$\tilde{y}_t \equiv y_t - y_t^n = \left[\mathbb{E}_t y_{t+1} - \frac{1}{\sigma}\left(i_t - \mathbb{E}_t \tilde{\pi}_{t+1} - \rho\right)\right] - \left[\mathbb{E}_t y_{t+1}^n - \frac{1}{\sigma}\left(r_t^n - \rho\right)\right].$$

This gives the IS equation as in the main text

$$\tilde{y}_t = \mathbb{E}_t \tilde{y}_{t+1} - \frac{1}{\sigma}\left(i_t - \mathbb{E}_t \tilde{\pi}_{t+1} - r_t^n\right).$$

To get the natural real interest rate, from $(A.1)$

$$\mathbb{E}_t \Delta y_{t+1} = \frac{1}{\sigma}\left(i_t - \mathbb{E}_t \tilde{\pi}_{t+1} - \rho\right).$$

Natural output is defined as

$$y_t^n = \psi_{ya}^n + \vartheta_y^n.$$

Taking the first difference of the above

$$\mathbb{E}_t \Delta y_{t+1}^n = \psi_{ya}^n \mathbb{E}_t \Delta a_{t+1}. \tag{A.4}$$

We then solve the main IS equation for r_t^n and use (A.4) to yield an expression for r_t^n as

$$r_t^n = i_t - \mathbb{E}_t \pi_{t+1} - \sigma\left(\mathbb{E}_t \tilde{y}_{t+1} - \tilde{y}_t\right).$$

Simplifying further,

$$r_t^n = i_t - \mathbb{E}_t \pi_{t+1} - \sigma\left(\mathbb{E}_t\left(y_{t+1} - y_{t+1}^n\right) - \left(y_t - y_t^n\right)\right) = i_t - \mathbb{E}_t \pi_{t+1} - \sigma\left(\mathbb{E}_t \Delta y_{t+1} - \mathbb{E}_t \Delta y_{t+1}^n\right).$$

This gives the final expression for the natural level of interest rate

$$r_t^n = \rho + \sigma \psi_{ya}^n \mathbb{E}_t \Delta a_{t+1}, \tag{A.5}$$

where $\psi^n_{ya} = \frac{1+\phi}{\phi+\sigma}$. This implies that the natural level of interest rate is a function of expected technological progress as well as households' discount rate.

A.6 Derivation of the NKPC

In this section, we show the derivation of the sectoral NKPCs in the case without accounting for the overweighting behaviour of the households.

The firm's profit maximization problem is given by:

$$\max_{p_{j,t^*}} \Sigma_{k=0}^{\infty} \theta_j^k \mathbb{E}_t \Big[Q_{t,t+k} \left(P^*_{j,t} Y_{j,t+k}(i) - TC^n_{j,t+k|t} \left(Y_{j,t+k}(i) \right) \right) \Big],$$

where $TC^n_{j,t+k|t}$ denotes the nominal total cost of the firm in sector j. Substituting the demand functions and using the market clearing conditions we get

$$\max_{p_{j,t^*}} \Sigma_{k=0}^{\infty} \theta_j^k \mathbb{E}_t \left[Q_{t,t+k} \left(P^*_{j,t} \left(\frac{P^*_{j,t}}{P_{j,t+k}} \right)^{-\epsilon_j} - TC^n_{j,t+k|t} \left(\left(\frac{P^*_{j,t}}{P_{j,t+k}} \right)^{-\epsilon_j} C_{j,t+k} \right) \right) \right].$$

Substituting the discount factor $Q_{t,t+k} = \beta^k \left(\frac{C_{t+k}}{C_t} \right)^{-\sigma} \frac{P_t}{P_{t+k}}$ and maximizing with respect to $P^*_{j,t}$. The FOC is:

$$\Sigma_{k=0}^{\infty} \theta_j^k \mathbb{E}_t \left[\beta^k \left(\frac{C_{t+k}}{C_t} \right)^{-\sigma} \frac{P_t}{P_{t+k}} \left((1-\epsilon_j) \left(\frac{P^*_{j,t}}{P_{j,t+k}} \right)^{-\epsilon_j} - MC^n_{j,t+k|t} \epsilon_j \left(\frac{P^*_{j,t}}{P_{j,t+k}} \right)^{-1-\epsilon_j} C_{j,t+k} \frac{1}{P_{j,t+k}} \right) \right] = 0.$$

This simplifies to

$$\Sigma_{k=0}^{\infty} \theta_N^k \mathbb{E}_t \left[\beta^k \left(\frac{C_{t+k}}{C_t} \right)^{-\sigma} \frac{P_t}{P_{t+k}} \left(\frac{P^*_{j,t}}{P_{j,t+k}} \right)^{-\epsilon_j} C_{j,t+k} \left(P^*_{j,t} - \frac{\epsilon_j}{1-\epsilon_j} MC^n_{j,t+k|t} \right) \right] = 0.$$

Using the sectoral prices to get the real marginal cost we get

$$\Sigma_{k=0}^{\infty} \theta_j^k \mathbb{E}_t \left[\beta^k \left(\frac{C_{t,t+k}}{C_t} \right)^{-\sigma} \frac{P_t}{P_{t+k}} \left(\frac{P^*_{j,t}}{P_{j,t+k}} \right)^{-\epsilon_j} C_{j,t+k} \left(P^*_{j,t} - \frac{\epsilon_j}{1-\epsilon_j} MC^r_{j,t+k|t} P_{j,t+k} \right) \right] = 0.$$

Solving further and dividing by $P_{j,t-1}$ throughout

$$\begin{aligned} &\frac{P_{j,t}*}{P_{j,t-1}} \Sigma_{k=0}^{\infty} \theta_j^k \mathbb{E}_t \left[\beta^k \left(\frac{C_{t,t+k}}{C_t} \right)^{-\sigma} \frac{P_t}{P_{t+k}} P^{\epsilon_j}_{j,+k} C_{j,t+k} \right] \\ &= \frac{\epsilon_j}{\epsilon_j - 1} \Sigma_{k=0}^{\infty} \theta_N^k \mathbb{E}_t \left[\beta^k \left(\frac{C_{t,t+k}}{C_t} \right)^{-\sigma} \frac{P_t}{P_{t+k}} \left(P^*_{j,t+k} \right)^{1+\epsilon_j} C_{j,t+k} MC^r_{j,t+k|t} \frac{1}{P_{j,t-1}} \right]. \end{aligned} \tag{A.6}$$

Consider the first-order Taylor expansion of the LHS:

$$\Sigma_{k=0}^{\infty}\theta_j^k\beta^k P_j^{\varepsilon_j} C_j \left[1+\left(\frac{P_{j,t}^{*}-P_j}{P_j}\right)-\left(\frac{P_{j,t-1}-P_j}{P_j}\right)+(-\sigma)\left(\frac{C_{t+k}-C}{C}\right)-(-\sigma)\left(\frac{C_t-C}{C}\right)\right.$$
$$\left.+\left(\frac{P_t-P}{P}\right)+\left(\frac{P_{t+k}-P}{P}\right)+\varepsilon_j\left(\frac{P_{j,t+k}-P_j}{P_j}\right)+\left(\frac{C_{j,t+k}-C_j}{C_j}\right)\right].$$

This gives the following:

$$\Sigma_{k=0}^{\infty}\theta_j^k\beta^k P_j^{\varepsilon_j} C_j[1+\left(p_{j,t}^{*}-p_j\right)-\left(p_{j,t-1}-p_j\right)+(-\sigma)\left(c_{t+k}-c\right)-(-\sigma)\left(c_t-c\right)$$
$$+\left(p_t-p\right)-\left(p_{t+k}-p\right)+\varepsilon_j\left(p_{j,t+k}-p_j\right)+\left(c_{j,t+k}-c_j\right)].$$

Consider the first-order Taylor expansion of the RHS:

$$\frac{\varepsilon_j}{\varepsilon_j-1}\Sigma_{k=0}^{\infty}\theta_j^k\mathbb{E}_t\beta^k P_j^{\varepsilon_j} C_j MC_N^r\left[1+(-\sigma)\left(\frac{C_{t+k}-C}{C}\right)-(-\sigma)\left(\frac{C_t-C}{C}\right)+(1+\varepsilon_j)\left(\frac{P_{j,t+k}-P_j}{P_j}\right)\right.$$
$$\left.-\left(\frac{P_{t+k}-P}{P}\right)+\left(\frac{P_t-P}{P}\right)+\left(\frac{C_{j,t+k}-C_j}{C_j}\right)-\left(\frac{P_{j,t-1}-P_j}{P_j}\right)+\left(\frac{MC_{j,t+k|t}^r-MC_j}{MC_j}\right)\right]$$

This simplifies to the following:

$$\frac{\varepsilon_j}{\varepsilon_j-1}\Sigma_{k=0}^{\infty}\theta_j^k\mathbb{E}_t\beta^k P_j^{\varepsilon_j} C_j MC_j^r[1+(-\sigma)\left(c_{t+k}-c\right)-(-\sigma)\left(c_t-c\right)+(1+\varepsilon_j)\left(p_{j,t+k}-p_j\right)$$
$$-\left(p_{t+k}-p\right)+\left(p_t-p\right)+\left(c_{j,t+k}-c_j\right)-\left(p_{j,t-1}-p_j\right)+\left(mc_{j,t+k|t}^r-mc_j\right)]. \tag{A.7}$$

Combining the LHS and RHS and cancelling common terms we get

$$\sum_{k=0}^{\infty}\theta_j^k\beta^j\mathbb{E}_t\left(p_{j,t}^{*}-p_{j,t+k}\right)=\frac{\varepsilon_j}{\varepsilon_j-1}MC_j^r\sum_{k=0}^{\infty}\theta_j^k\beta^k\mathbb{E}_t\left[mc_{j,t+k|t}^r-mc_j^r\right].$$

This simplifies to

$$p_{j,t}^{*}=(1-\theta_j\beta)\sum_{k=0}^{\infty}\theta_j^k\beta^k\mathbb{E}_t\left[mc_{j,t+k|t}^r-mc_j^r+p_{j,t+k}\right].$$

Substituting $mc_{j,t+k|t}^r=mc_{j,t+k}^r$ and $mc_{j,t+k}^r-mc_j^r=\hat{mc}_{j,t+k}^r$ we get

$$p_{j,t}^{*}=(1-\theta_j\beta)\sum_{k=0}^{\infty}\theta_j^k\beta^k\mathbb{E}_t\left[\hat{mc}_{j,t+k}^r+p_{j,t+k}\right]. \tag{A.8}$$

Subtracting $p_{j,t-1}$ from both sides and simplifying in multiple steps, we get the following:

$$
\begin{aligned}
p_{j,t}^{*} - p_{j,t-1} &= (1-\theta_j\beta)\sum_{k=0}^{\infty}\theta_j^k\beta^k\mathbb{E}_t\left[\hat{mc}_{j,t+k}^{r} + p_{j,t+k} - p_{j,t-1}\right], \\
&= (1-\theta_j\beta)\sum_{k=0}^{\infty}\theta_j^k\beta^k\mathbb{E}_t\hat{mc^r}_{j,t+k} + (1-\theta\beta)\sum_{k=0}^{\infty}\theta_j^k\beta^k\mathbb{E}_t\left(p_{j,t+k} - p_{j,t-1}\right), \\
&= (1-\theta_j\beta)\sum_{k=0}^{\infty}\theta_j^k\beta^k\mathbb{E}_t\hat{mc^r}_{j,t+k} + (1-\theta_j\beta)\,\mathbb{E}_t\left[\theta_j^0\beta^0\left(p_{j,t} - p_{j,t-1}\right) + \theta_j^1\beta^1\left(p_{j,t+1} - p_{j,t}\right.\right. \\
&\left. + p_{j,t} - p_{j,t-1} + \theta_j^2\beta^2\left(p_{j,t+2} - p_{j,t+1} + p_{j,t+1} - p_{j,t} + p_{j,t} - p_{j,t-1}\right) + \ldots\right., \\
&= (1-\theta_j\beta)\sum_{k=0}^{\infty}\theta_j^k\beta^k\mathbb{E}_t\hat{mc^r}_{j,t+k} + \mathbb{E}_t\left[\theta_j^0\beta^0\pi_{j,t} + \theta_j^1\beta^1\pi_{j,t+1} + \theta_j^2\beta^2\pi_{j,t+2} + \ldots\right], \\
&= (1-\theta_j\beta)\sum_{k=0}^{\infty}\theta_j^k\beta^k\mathbb{E}_t\hat{mc^r}_{j,t+k} + (1-\theta_j\beta)\sum_{k=0}^{\infty}\theta_j^k\beta^k\mathbb{E}_t\left(\pi_{j,t+k}\right).
\end{aligned}
$$

We can take out $k = 0$ terms from each of the summation operator to write the above equation compactly as a difference equation and using $\pi_{j,t} = (1-\theta_j)\left(p_{j,t}^{*} - p_{j,t-1}\right)$ we get

$$
\begin{aligned}
p_{j,t}^{*} - p_{j,t-1} &= \theta_N\beta\left[(1-\theta_N\beta)\sum_{k=0}^{\infty}\theta_j^k\beta^k\mathbb{E}_t\hat{mc^r}_{j,t+k+1} + \sum_{k=0}^{\infty}\theta_j^k\beta^k\mathbb{E}_t\left(\pi_{j,t+k+1}\right)\right] + (1-\theta_j\beta)\,\hat{mc}_{j,t}^{r} + \pi_{j,t}, \\
&= \theta_j\beta\mathbb{E}_t\left(p_{j,t+1}^{*} - p_{j,t}\right) + (1-\theta_j\beta)\,\hat{mc^r}_{j,t} + (1-\theta_j)\left(p_{j,t}^{*} - p_{j,t-1}\right), \\
&= \beta\left(1-\theta_j\right)\mathbb{E}_t\left(p_{j,t+1}^{*} - p_{j,t}\right) + \left(\frac{(1-\theta_j)\left(1-\theta_j\beta\right)}{\theta_j}\right)\hat{mc}_{j,t}^{r}.
\end{aligned}
$$

This gives the NKPC in terms of marginal cost as follows:

$$
\pi_{j,t} = \beta\mathbb{E}_t\pi_{j,t+1} + \chi_j\hat{mc}_{j,t}^{r},
$$

where $\chi_j = \frac{(1-\theta_j)(1-\theta_j\beta)}{\theta_j}$.
Using the aggregation of sectoral prices, we define relative prices as $S_t = \frac{P_{O,t}}{P_{N,t}}$. Then,

$$
P_t = P_{N,t}^{1-\omega}P_{O,t}^{\omega} = P_{N,t}\left(\frac{P_{O,t}}{P_{N,t}}\right)^{\omega} = P_{N,t}S_t^{\omega}.
$$

Linearizing the above gives, $p_t = p_{N,t} + \omega s_t = p_{H,t} + (\omega-1)\,s_t$.

The real marginal cost of a firm in sector N can be defined as follows:

$$
\begin{aligned}
mc^r_{N,t} &= w_t - p_{N,t} - a_{N,t}, \\
&= w_t - p_t + \omega s_t - a_{N,t}, \\
&= \sigma y_t + \phi l_t - a_{N,t} + \omega s_t, \\
&= \sigma y_t + \phi y_t - \phi a_t - a_{N,t} + \omega s_t, \\
&= (\sigma + \phi) y_{N,t} - (\sigma + \phi)\omega s_t - \phi a_t - a_{N,t} + \omega s_t, \\
&= (\sigma + \phi) y_{N,t} + (1 - \sigma - \phi)\omega s_t - \phi a_t - a_{N,t},
\end{aligned}
$$

where we have used the household's labour supply condition: $w_t - p_t = \sigma c_t + \phi l_t$, demand relation: $c_{N,t} = \omega s_t + c_t$ and market clearing condition $c_{N,t} = y_{N,t}$. Then

$$mc^r_N = -\mu_N = (\sigma + \phi) y^n_{N,t} - \phi a_t - a_{N,t} + (1 - \sigma - \phi)\omega s^n_t.$$

Therefore, $\hat{mc}^r_{N,t} = mc^r_{N,t} - mc^r_N = (\sigma + \phi)\tilde{y}_{N,t} + (1 - \sigma - \phi)\omega \tilde{s}_t$ Hence, the sectoral NKPC for sector N is

$$\pi_{N,t} = \beta \mathbb{E}_t \pi_{N,t+1} + \chi_N \left((\sigma + \phi)\tilde{y}_{N,t} + (1 - \sigma - \phi)\omega \tilde{s}_t\right).$$

Similarly, the sectoral NKPC for sector O is

$$\pi_{O,t} = \beta \mathbb{E}_t \pi_{O,t+1} + \chi_H \left((\sigma + \phi)\tilde{y}_{O,t} + (\sigma + \phi - 1)(1 - \omega)\tilde{s}_t\right).$$

A.7 Derivation of central bank's loss function

Consider the utility function of the representative household

$$\mathbb{U} = \mathbf{U}\left(\mathrm{C_{N,t}}, \mathrm{C_{O,t}}\right) - \mathbf{V}\left(\mathrm{L_{N,t}}, \mathrm{L_{O,t}}\right). \tag{A.9}$$

To derive the welfare function from the utility function, consider the second-order approximation of the utility from the consumption of the two goods. We know $\mathbf{U}\left(\mathbf{C_t}\right) = \frac{\mathbf{C_t^{1-\sigma}}}{\mathbf{1-\sigma}}$ and $\mathbf{C_t} = \left(\mathrm{C_{N,t}}\right)^{1-\omega}\left(C_{O,t}\right)^{\omega}$. Then

$$\begin{aligned}\mathbf{U}\left(\mathrm{C_{N,t}}, \mathrm{C_{O,t}}\right) = {} & U\left(C_N, C_O\right) + U'_{C_N}\left(C_{N,t} - C_N\right) + U'_{C_O}\left(C_{O,t} - C_O\right) + \frac{1}{2}U''_{C_N}\left(C_{N,t} - C_N\right)^2 \\ & + \frac{1}{2}U''_{C_O}\left(C_{O,t} - C_O\right)^2 + U''_{C_N C_O}\left(C_{N,t} - C_N\right)\left(C_{O,t} - C_O\right) + O\left\|\xi\right\|^3,\end{aligned} \tag{A.10}$$

where $O\left\|\xi\right\|^3$summarizes all the terms of the third and higher order.
We know, $\frac{C_{j,t}-C_j}{C_j} = \hat{c}_{j,t} + \frac{1}{2}\hat{c}_{j,t}^2$ where $\hat{c}_{j,t} = log\left(\frac{C_{j,t}}{C_j}\right)$ is the log deviation from the steady state under sticky prices. Substituting the derivative and writing in log deviations from steady state

$$\begin{aligned}\boldsymbol{U}\left(C_{N,t}, C_{H,t}\right) \approx {} & U\left(C_N, C_H\right) + U'_{C_N}C_N\Bigg[\hat{c}_{N,t} + \frac{1}{2}\hat{c}_{N,t}^2 + \frac{\sigma\left(\omega-1\right)-\omega}{2}\left(\hat{c}_{N,t} + \frac{1}{2}\hat{c}_{N,t}^2\right)^2 \\ & + \omega\left(1-\sigma\right)\left(\hat{c}_{N,t} + \frac{1}{2}\hat{c}_{N,t}^2\right)\left(\hat{c}_{O,t} + \frac{1}{2}\hat{c}_{O,t}^2\right)\Bigg] \\ & + U'_{C_O}C_O\left[\hat{c}_{O,t} + \frac{1}{2}\hat{c}_{O,t}^2 + \frac{\omega\left(1-\sigma\right)-1}{2}\left(\hat{c}_{O,t} + \frac{1}{2}\hat{c}_{O,t}^2\right)^2\right] + O\left\|\xi\right\|^3.\end{aligned} \tag{A.11}$$

Substituting $U'_cC = \left(1-\omega\right)U'_{C_N}C_N = \omega U'_{C_O}C_O$ in the above and simplifying

$$\begin{aligned}\boldsymbol{U}\left(C_t\right) - U\left(C\right) \approx {} & U'_C C\Bigg[\left(1-\omega\right)\hat{c}_{N,t} + \omega\hat{c}_{O,t} + \left(\frac{1-\sigma}{2}\right)\left(1-\omega\right)^2\hat{c}_{N,t}^2 + \left(\frac{1-\sigma}{2}\right)\omega^2\hat{c}_{O,t}^2 \\ & + \omega\left(1-\omega\right)\left(1-\sigma\right)\hat{c}_{N,t}\hat{c}_{O,t}\Bigg] + O\left\|\xi\right\|^3.\end{aligned} \tag{A.12}$$

Next, we consider the disutility of labour for the households

$$V\left(L\right) = \frac{L_t^{1+\phi}}{1+\phi}, \tag{A.13}$$

where $L_t = L_{N,t} + L_{O,t}$. The second-order approximation of this function is

$$V\left(L_{N,t}, L_{H,t}\right) \approx V\left(L_N, L_O\right) + V'_{L_N}\left(L_{N,t} - L_N\right) + V'_{L_O}\left(L_{O,t} - L_O\right) + \frac{1}{2}V''_{L_N}\left(L_{N,t} - L_N\right)^2$$
$$+\frac{1}{2}V''_{L_O}\left(L_{O,t} - L_O\right)^2 + V''_{L_N L_O}\left(L_{N,t} - L_N\right)\left(L_{O,t} - L_O\right) + O\left\|\xi\right\|^3. \tag{A.14}$$

Let $\frac{L_N}{L} = (1-\omega)$and $\frac{L_O}{L} = \omega$. Substituting the derivatives and further simplifying

$$V\left(L_t\right) - V\left(L\right) \approx V'_L L\Bigg[\left(1-\omega\right)\hat{l}_{N,t} + \left(\frac{1-\omega}{2}\right)\hat{l}^2_{N,t} + \omega\hat{l}_{O,t} + \frac{\omega}{2}\hat{l}^2_{O,t}$$
$$+\frac{\phi}{2}\left(1-\omega\right)^2\hat{l}^2_{N,t} + \frac{\phi}{2}\omega^2\hat{l}^2_{O,t} + \phi\omega\left(1-\omega\right)\hat{l}_{N,t}\hat{l}_{O,t}\Bigg] + O\left\|\xi\right\|^3. \tag{A.15}$$

Combine equations $(A.12)$, $(A.15)$ and substitute $V'_L L = -U'_C C$ to get the welfare function

$$\mathcal{W} \approx U'_C C\Bigg[\left(1-\omega\right)\hat{c}_{N,t} + \omega\hat{c}_{O,t} + \left(\frac{1-\sigma}{2}\right)\left(1-\omega\right)^2\hat{c}^2_{N,t} + \left(\frac{1-\sigma}{2}\right)\omega^2\hat{c}^2_{O,t}$$
$$+\omega\left(1-\omega\right)\left(1-\sigma\right)\hat{c}_{N,t}\hat{c}_{O,t} - \left(1-\omega\right)\hat{l}_{N,t} - \left(\frac{1-\omega}{2}\right)\hat{l}^2_{N,t} - \omega\hat{l}_{O,t} - \frac{\omega}{2}\hat{l}^2_{O,t}$$
$$-\frac{\phi}{2}\left(1-\omega\right)^2\hat{l}^2_{N,t} - \frac{\phi}{2}\omega^2\hat{l}^2_{O,t} - \phi\omega\left(1-\omega\right)\hat{l}_{N,t}\hat{l}_{O,t}\Bigg] + O\left\|\xi\right\|^3. \tag{A.16}$$

We know $\hat{l}_{j,t} = \hat{y}_{j,t} - a_{j,t} + d_{j,t}\forall j = N, O$ where

$$d_{jt} = log\int_0^1\left(\frac{P_{jt}(i)}{P_{jt}}\right)^{-\varepsilon_{jt}} di. \tag{A.17}$$

Also, from market clearing we have $\hat{c}_{j,t} = \hat{y}_{j,t}$. Substituting in $(A.16)$

$$\frac{\mathcal{W}}{U'_C C} \approx \left(1-\omega\right)\hat{y}_{N,t} + \omega\hat{y}_{O,t} + \left(\frac{1-\sigma}{2}\right)\left(1-\omega\right)^2\hat{y}^2_{N,t} + \left(\frac{1-\sigma}{2}\right)\omega^2\hat{y}^2_{O,t} + \omega\left(1-\omega\right)\left(1-\sigma\right)\hat{y}_{N,t}\hat{y}_{O,t}$$
$$-\left(1-\omega\right)\hat{y}_{N,t} - \left(1-\omega\right)d_{N,t} - \left(\frac{1-\omega}{2}\right)\hat{y}^2_{N,t} + \left(1-\omega\right)\hat{y}_{N,t}a_{N,t} - \omega\hat{y}_{O,t} - \left(\frac{\omega}{2}\right)^2\hat{y}^2_{O,t} - {}_{O,t}$$
$$+\omega\hat{y}_{O,t}a_{O,t} - \frac{\phi}{2}\left(1-\omega\right)^2\hat{y}^2_{N,t} + \phi\left(1-\omega\right)^2\hat{y}_{N,t}a_{N,t} - \frac{\phi}{2}\left(1-\omega\right)^2\hat{y}^2_{O,t} + \phi\omega^2\hat{y}_{O,t}a_{O,t}$$
$$-\phi\omega\left(1-\omega\right)\hat{y}_{N,t}\hat{y}_{O,t} + \phi\omega\left(1-\omega\right)\hat{y}_{N,t}a_{O,t} + \phi\omega\left(1-\omega\right)\hat{y}_{O,t}a_{N,t} + t.i.p + O\left\|\xi\right\|^3, \tag{A.18}$$

where $t.i.p$ includes all the terms independent of policy.
The linear terms in (A.18) cancel out. Consider first the following quadratic terms

$$-\left(\frac{1-\omega}{2}\right)\hat{y}^2_{N,t} + \left(1-\omega\right)\hat{y}_{N,t}a_{N,t} = -\left(\frac{1-\omega}{2}\right)\left[\hat{y}^2_{N,t} - 2\hat{y}_{N,t}a_{N,t}\right]. \tag{A.19}$$

Substituting $a_{N,t} = \hat{y}^n_{N,t} - \hat{y}^n_t + a_t$ (where $\hat{y}^n_t$and $\hat{y}^n_{N,t}$are flexible price aggregate and sectoral outputs, respectively) in $(A.19)$

$$-\left(\frac{1-\omega}{2}\right)\hat{y}^2_{N,t} + (1-\omega)\,\hat{y}_{N,t}a_{N,t} = -\left(\frac{1-\omega}{2}\right)\left[\tilde{y}^2_{N,t} - \left(\hat{y}^n_{N,t}\right)^2 + 2\hat{y}_{N,t}\hat{y}^n_t - 2\hat{y}_{N,t}a_t\right], \tag{A.20}$$

where $\tilde{y}_{N,t} = \hat{y}_{N,t} - \hat{y}^n_{N,t}$.
Similarly, the quadratic terms for sector O can be simplified to

$$-\left(\frac{\omega}{2}\right)\hat{y}^2_{O,t} + \omega y\hat{O}_{,t}a_{O,t} = -\left(\frac{\omega}{2}\right)\left[\tilde{y}^2_{O,t} - \left(\hat{y}^n_{O,t}\right)^2 + 2\hat{y}_{O,t}\hat{y}^n_t - 2\hat{y}_{O,t}a_t\right]. \tag{A.21}$$

Next, we simplify the following quadratic terms as

$$\begin{aligned}&\left(\frac{1-\sigma}{2}\right)\left[(1-\omega)^2\hat{y}^2_{N,t} + \omega^2\hat{y}^2_{O,t} + 2\omega(1-\omega)\,\hat{y}_{N,t}\hat{y}_{O,t}\right]\\&-\frac{\phi}{2}\left[(1-\omega)^2\hat{y}^2_{N,t} + \omega^2\hat{y}^2_{O,t} + 2\omega(1-\omega)\,\hat{y}_{N,t}\hat{y}_{O,t}\right]\\&=\left(\frac{1-\sigma-\phi}{2}\right)\hat{y}^2_t.\end{aligned} \tag{A.22}$$

The remaining terms in $(A.18)$ can be simplified to

$$\phi(1-\omega)^2\hat{y}_{N,t}a_{N,t} + \phi\omega(1-\omega)\,\hat{y}_{O,t}a_{N,t} + \phi\omega^2\hat{y}_{O,t}a_{O,t} + \phi\omega(1-\omega)\,\hat{y}_{N,t}a_{O,t} = \phi\hat{y}_t a_t,$$

since $(1-\omega)\,a_{N,t} + \omega a_{O,t} \equiv a_t$. Also, at flexi-price equilibrium $\hat{y}^n_t = \frac{1+\phi}{\sigma+\phi}a_t$ so

$$\phi\hat{y}_t a_t = \phi\left(\frac{\sigma+\phi}{1+\phi}\right)\hat{y}_t\hat{y}^n_t. \tag{A.23}$$

Combining $(A.20)$, $(A.21)$, $(A.22)$, and $(A.23)$, the welfare loss function is

$$\begin{aligned}\frac{\mathcal{W}}{U'_C C} \approx &-\left(\frac{1-\omega}{2}\right)\tilde{y}^2_{N,t} - \frac{\omega}{2}\tilde{y}^2_{O,t} + \frac{1-\sigma-\phi}{2}\hat{y}^2_t - (1-\sigma-\phi)\,\hat{y}_t\hat{y}^n_t\\&-(1-\omega)\,d_{N,t} - \omega d_{O,t} + t.i.p + O\,\|\xi\|^3.\end{aligned}$$

Completing the squares in terms of aggregate output

$$\begin{aligned}\frac{\mathcal{W}}{U'_C C} \approx &-\frac{1}{2}E_0\Sigma^\infty_{t=0}\beta^t\left[(1-\omega)\,\tilde{y}^2_{N,t} + \omega\tilde{y}^2_{O,t} + \left(\frac{\sigma+\phi-1}{2}\right)\tilde{y}^2_t + 2(1-\omega)\,d_{N,t} + 2\omega d_{O,t}\right]\\&+t.i.p + O\,\|\xi\|^3.\end{aligned} \tag{A.24}$$

In section (A.7.1), we show that $d_{j,t} = \sum^\infty_{t=0}\beta^t var_i p_{j,t}\,(i)$.

Based on Woodford (2003) Proposition 6.3, we know

$$\sum_{t=0}^{\infty} \beta^t var_i p_{j,t}(i) = \frac{1}{\chi_j} \sum_{t=0}^{\infty} \beta^t \pi_{j,t}^2,$$

where $\chi_j = \frac{(1-\theta_j)(1-\beta\theta_j)}{\theta_j}$. Therefore

$$\sum_{t=0}^{\infty} \beta^t \frac{\varepsilon_j}{2} var_i p_{j,t}(i) = \frac{\varepsilon_j}{2\chi_j} \sum_{t=0}^{\infty} \beta^t \pi_{j,t}^2. \tag{A.25}$$

Substituting for $d_{j,t}$ in $(A.24)$, the welfare loss function is

$$\begin{aligned} \frac{\mathcal{W}}{U_C' C} \approx -\frac{1}{2} E_0 \Sigma_{t=0}^{\infty} \beta^t \Big[& (1-\omega)\, \tilde{y}_{N,t}^2 + \omega \tilde{y}_{O,t}^2 + (\sigma+\phi-1)\, \tilde{y}_t^2 \\ & + \frac{\varepsilon_N}{\chi_N} (1-\omega)\, \pi_{N,t}^2 + \frac{\varepsilon_O}{\chi_O} \omega \pi_{O,t}^2 \Big] + t.i.p + O\, \|\xi\|^3 . \end{aligned} \tag{A.26}$$

A.7.1 Second-order approximation of price dispersion

We know that

$$\hat{l}_{j,t} = (\hat{y_{jt}} - \alpha_{jt} + d_{jt}),$$

where

$$d_{jt} = log \int_0^1 \left(\frac{P_{jt}(i)}{P_{jt}} \right)^{-\varepsilon_{jt}} di. \tag{A.27}$$

We use the second-order approximation of $\left(\frac{P_{jt}(i)}{P_{jt}} \right)^{1-\varepsilon_j}$, where $\hat{p}_{jt}(i) = p_{jt}(i) - p_{jt}$ is approximated around zero such that

$$\left(\frac{P_{jt}(i)}{P_{jt}} \right)^{1-\varepsilon_j} = exp(1-\varepsilon_j)\,(p_{jt}(i) - p_{jt}) = exp(1-\varepsilon_j)\,(\hat{p}_{jt}(i)) .$$

The second-order approximation is

$$\left(\frac{P_{jt}(i)}{P_{jt}} \right)^{1-\varepsilon_j} \approx 1 + (1-\varepsilon_j)\,(\hat{p}_{jt}(i)) + \frac{1}{2}(1-\varepsilon_j)^2\,(\hat{p}_{jt}(i))^2 . \tag{A.28}$$

From the definition of sectoral price index, $P_{jt} = \left(\int_0^1 P_{jt}(i)^{1-\varepsilon_j} di \right)^{\frac{1}{1-\varepsilon_j}}$, we have

$$1 = \left(\int_0^1 \left(\frac{P_{jt}(i)}{P_{jt}} \right)^{1-\varepsilon_j} di \right)^{\frac{1}{1-\varepsilon_j}} .$$

Taking Expectations of both sides of A.28

$$E_i\left(\left(\frac{P_{jt}(i)}{P_{jt}}\right)^{1-\varepsilon_j}\right) \approx E_i\left[1+(1-\varepsilon_j)\left(\hat{p}_{jt}(i)\right)+\frac{1}{2}(1-\varepsilon_j)^2\hat{p}_{jt}(i)^2\right],$$

where E_i denotes the expectations operator with respect to good i. This can be further simplified to

$$E_i\hat{p}_{jt}(i) \approx -\frac{1}{2}(1-\varepsilon_j)E_i\left(\hat{p}_{jt}(i)^2\right) = -\frac{1}{2}(1-\varepsilon_j)Var_i\hat{p}_{jt}(i). \tag{A.29}$$

Next, we do a second order approximation of $\left(\frac{P_{jt}(i)}{P_{jt}}\right)^{-\varepsilon_j}$ in d_{jt}

$$\left(\frac{P_{jt}(i)}{P_{jt}}\right)^{-\varepsilon_j} \approx 1-\varepsilon_j\hat{p_{jt}}(i)+\frac{1}{2}\varepsilon_j^2\hat{p_{jt}}(i)^2. \tag{A.30}$$

Finally, substitute equations (A.29) and (A.30) into equation (A.17) to get the second order approximation of d_{jt}

$$d_{jt} \approx log\left\{\int_0^1\left[1-\varepsilon_j\hat{p}_{jt}(i)+\frac{1}{2}\varepsilon_j^2p_{jt}(i)^2\right]di\right\},$$

which further simplifies to

$$d_{jt} \approx \frac{\varepsilon_j}{2}varp_{jt}(i).$$

A.8 Parameters

Table A.10: Parameters and standard deviation of shocks

Parameter		Value
Discount factor	β	0.99
Inverse IES	σ	1
Inverse Frisch elasticity of labour supply	ϕ	5
Elasticity of substitution between goods (N)	ε_N	9
Elasticity of substitution between goods (O)	ε_O	9
Price stickiness in sector N	θ_N	0.75
Price stickiness in sector O	θ_O	0.75
Cost-push shock persistence in sector N	ρ_{u_N}	0.8
Cost-push shock persistence in sector O	ρ_{u_O}	0.8
Technology shock persistence in sector N	ρ_{a_N}	0.9
Technology shock persistence in sector O	ρ_{a_O}	0.9
Share of housing in consumption	ω	0.5
Overweighting paramater	δ	0.3
Cost-push shock in N standard deviation	σ_{u_N}	1
Cost-push shock in O standard deviation	σ_{u_O}	1

Notes: The parameter values are from Galí (2015). At this stage, we have used standard values of the parameters, and have kept the two sectors, O and N, to be symmetric.