Monetary Transmission to Prices: Disaggregated Evidence from Norway*

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Abstract

We investigate how monetary policy affects disaggregated consumer prices in Norway. There are three main findings. First, there is a tendency for prices to decline in response to a higher interest rate, but the response is delayed and uncertain. Second, the average response hides dispersion. A higher interest rate reduces some prices, most prominently *accommodation services* and *food and non-alcoholic beverages*, and raises other prices, such as *rentals for housing*. Third, we explore the cost, aggregate demand, and exchange rate channels of monetary policy. We find the clearest evidence for the cost channel: sectors with high debt as a share of total costs raise prices in response to higher interest rates. Our results are also consistent with the aggregate demand and exchange rate channels, but the estimates for these two channels are imprecise and remain inconclusive.

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1 Introduction

What is the effect of higher interest rates on consumer prices? And through which mechanisms does this effect operate? For a central bank charged with maintaining price stability, these questions are foundational: the mandate presupposes that the policy rate exerts a measurable influence on the price level. A substantial empirical literature supports the proposition that an increase in the policy rate is, on average, associated with a subsequent decline in prices (Romer and Romer, 2004; Christiano, Eichenbaum, and Evans, 2005; Boivin, Giannoni, and Mihov, 2009; Aruoba and Drechsel, 2024). The estimated effects, however, are characterized by "long and variable lags": considerable transmission delays and non-trivial uncertainty around the point estimates.

Standard textbook treatments offer several mechanisms consistent with this empirical regularity. A higher policy rate is expected to dampen aggregate demand, thereby exerting downward pressure on prices. In open-economy settings, it may further induce a nominal appreciation of the exchange rate, lowering the price of imported goods. These demand- and exchange-rate-based channels, however, are not exhaustive. The cost channel, where higher interest rates raise firms' financing costs and place upward pressure on prices, operates in the opposite direction and complicates the conventional account of monetary transmission.

This study asks how monetary policy transmits to consumer prices. We examine the case of Norway, a small open economy with a floating exchange rate and a flexible inflation-targeting regime. Using monetary policy shocks from Holm, Paul, and Tischbirek (2021) as instruments for interest rate changes, we estimate their effects on sub-indices of the monthly Consumer Price Index over the period 2001–2018.

Our first exercise estimates the response of aggregate and average consumer prices to changes in the interest rate. A 100-basis-point increase reduces prices by nearly 2% after five years, but the effect is delayed and imprecisely estimated: the 95 percent confidence band spans a reduction of 4% to an increase of 1%, and the response becomes economically meaningful only after several years. The magnitude and timing of this aggregate response are consistent with prior evidence for Norway (Holm, Paul, and Tischbirek, 2021) and the United States (Aruoba and Drechsel, 2024).

Disaggregating to the level of individual CPI sub-indices reveals substantial heterogeneity. Some prices fall significantly when rates increase, most notably *accommodation services* and *food and non-alcoholic beverages*. Others rise significantly, such as *rentals for housing*. In contrast to the U.S. evidence (Aruoba and Drechsel, 2024), we find little support for a strong common price response, suggesting that no single transmission channel

dominates across categories. Instead, the dispersion points to monetary policy reaching different prices through different mechanisms.

To interpret this heterogeneity, we examine three transmission channels: the cost, aggregate demand, and exchange rate channels.

We begin with the cost channel (Barth and Ramey, 2001), for which the evidence is clearest. Higher interest rates raise firms' financing costs, particularly for those carrying substantial debt, and should therefore push prices upward most strongly in sectors where interest expenses constitute a large share of costs. We proxy firms' interest rate exposure by their debt relative to costs and by net working capital relative to sales. The evidence points to a meaningful role for this channel: sectors with higher average debt-to-cost ratios cut prices less (or even raise prices) in response to an interest rate increase. The effect is statistically significant and economically sizeable. Moving from a debt-to-cost ratio of 0 to 2 (the CPI-weighted sample average) is associated with an additional 0.8-percentage-point increase in prices after four years, and the effect is several times larger for the high-debt rental sectors, where debt-to-cost ratios reach roughly 8. The result is driven primarily by sectors with very high debt shares of total costs, most notably rentals for housing, where prices rise rather than fall following a monetary tightening.

We next consider the aggregate demand channel, which predicts that a higher interest rate lowers demand and eventually induces most firms to cut prices, producing a common factor across categories analogous to the U.S. results (Aruoba and Drechsel, 2024). Even at long horizons, however, the dispersion in price responses remains substantial in our data, suggesting that the aggregate demand channel operates more weakly in Norway than in the U.S.

Grouping categories into durables, non-durables, and services sharpens the picture. Price responses for durables and services remain imprecisely estimated, but non-durable prices decline significantly following an interest rate increase. One plausible reason is that non-durables (and services, which have similarly-sized point estimates) depend more heavily on domestic costs, particularly wages, than durables. Consistent with this interpretation, total wages, hours worked, and wages per hour all decline in response to a higher interest rate. Taken together, these results are consistent with an aggregate demand channel operating through wages.

Why might the aggregate demand channel be weaker in Norway than in the United States? Norway's wage-setting institutions offer a candidate explanation. Under the country's system of pattern bargaining (Aukrust, 1977), wage growth across the economy is anchored to what the internationally exposed export sector can sustain, rather than set sector by sector in response to local conditions. This arrangement is designed precisely

to insulate domestic wages from fluctuations in domestic demand. If it functions as intended, a contraction in aggregate demand should pass through to wages more slowly and more weakly than in economies with decentralized wage setting. The contrast with Aruoba and Drechsel (2024), who document a strong common price response in the United States, is consistent with this interpretation: where wages are determined by pattern wage bargaining, the demand channel transmits to prices through a narrower and more sluggish door. The gradual, lagged decline in wages per hour that we document below is what such a mechanism would predict.

Finally, we turn to the exchange rate channel. Standard theory predicts that a surprise increase in the interest rate generates an immediate appreciation, which can in turn lower the prices of imported goods. Consistent with prior evidence, we find that a higher interest rate appreciates the Norwegian krone, measured by the import-weighted I-44 index: a 100-basis-point increase produces a roughly 6% appreciation after about 12 months.

Whether this appreciation passes through to consumer prices is a separate question. To gauge the strength of the exchange rate channel, we estimate how price responses to monetary policy vary with import exposure, measured both as imported inputs embodied in domestic production and as directly imported final consumption. Indices with higher import content tend to fall more following an interest rate increase, in line with the predicted mechanism, but the estimates are imprecise, and the evidence remains inconclusive.

Our conclusions are tempered by the uncertainty surrounding the estimates. Interest rate changes do appear to affect prices, but with a delay and considerable imprecision. The evidence is consistent with an aggregate demand channel, albeit one weaker than in other economies, and with an exchange rate channel, albeit imprecisely identified. The cost channel, by contrast, emerges more clearly: higher interest rates push prices upward in sectors with substantial debt burdens, particularly housing rentals.

Related literature. This paper contributes to three strands of literature.

A growing literature investigates how monetary policy affects disaggregated price indices. Some early contributors to this literature have mostly focused on how monetary policy affects prices, depending on the relative price stickiness of the sectors (Bils, Klenow, Kryvtsov, et al., 2003; Boivin, Giannoni, and Mihov, 2009) or on exploring variations in channels across sectors (Barth and Ramey, 2001; Ravenna and Walsh, 2006; Balke and Wynne, 2007; Baumeister, Liu, and Mumtaz, 2013). The recent inflation episode has led to a renewed interest in this topic, spurring a literature exploring heterogeneity in price responses to monetary policy more broadly (Borio, Disyatat, Xia, and Zakrajšek, 2021; Luo and Villar, 2023; Guerrieri, Marcussen, Reichlin, and Tenreyro, 2023; Buda, Carvalho,

Corsetti, Duarte, Hansen, Moura, Ortiz, Rodrigo, Rodríguez Mora, and Alves da Silva, 2025; Arnaut and Bengali, 2024; Aruoba and Drechsel, 2024). Our contribution to this literature is to examine how prices respond to monetary policy in a small open economy where we expect monetary transmission channels to operate differently. For example, in contrast to Aruoba and Drechsel (2024), our evidence suggests that there is less of a common price response across sectors, and thus that monetary transmission is less dominated by one common monetary transmission channel.

Our paper relates specifically to the evidence on the cost channel of monetary policy. Barth and Ramey (2001) present evidence suggesting the existence of a cost channel because in many industries output falls while price-wage ratios rise after a contractionary monetary policy shock. Similarly, Ravenna and Walsh (2006) construct and estimate a New Keynesian model where interest rate changes directly affect firms' debt service costs. On the empirical side, Gaiotti and Secchi (2006) document pricing behavior consistent with a cost channel in a large panel of Italian firms. The recent inflation episode has renewed interest in this channel: using euro-area firm-level data, Albertazzi, Ferrando, Gori, and Rariga (2025) and Core, De Marco, Eisert, and Schepens (2025) find that firms with greater reliance on debt and working capital raise prices following monetary tightening. We contribute to this literature by providing direct evidence of a cost channel of monetary policy where prices tend to rise in response to an interest rate increase in sectors with a high debt share relative to total costs.

Our paper also relates to the literature on monetary transmission to prices in Norway. Several papers examine how monetary policy affects the aggregate consumer price index (see, e.g., Holm, Paul, and Tischbirek, 2021), or specific prices such as the exchange rate (Bjørnland, 2008; Holm, Paul, and Tischbirek, 2021; Bjørnland, Brubakk, and Maffei-Faccioli, 2024) or house and stock prices (Bjørnland and Jacobsen, 2010, 2013; Robstad, 2018; Larsen, 2018; Rosenberg, 2019; Holm, Paul, and Tischbirek, 2021). We contribute to this literature by estimating the price response of disaggregated price series to monetary policy, and by exploring the role of several monetary transmission channels to prices in Norway.

2 Data

Prices. Statistics Norway classifies price indices following the United Nations Statistics Division's *Classification of Individual Consumption according to Purpose* (COICOP). The analysis in this paper is at the 3-digit level. Table A.1 in Appendix A lists all price indices. Measuring prices in an economy presents several challenges that may impact the inter-

pretation of our results. We discuss these challenges and how we address them in this section.

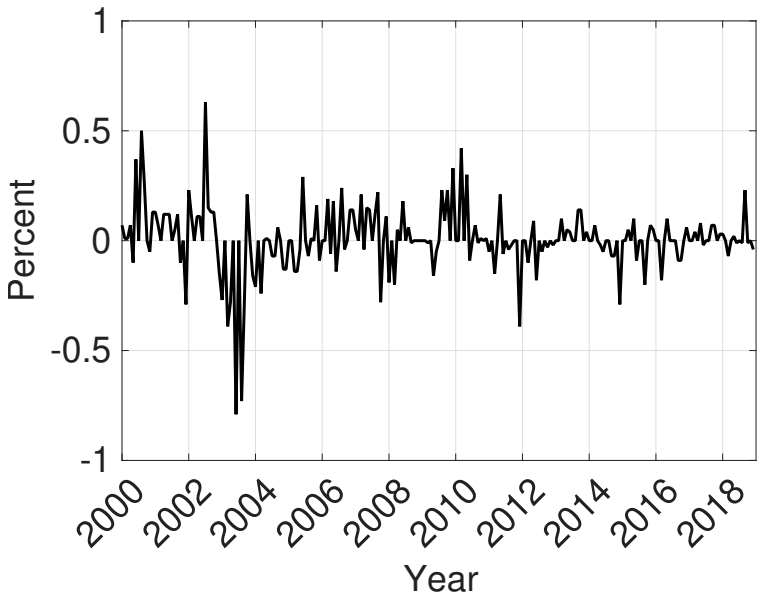
First, there is dispersion in the extent to which prices are measured precisely. Some prices, such as "food and beverages," are calculated using vendor scanner data. These are measured precisely as they are derived from transactions across the entire product dimension. Other prices are calculated from samples of representative goods and vendors. For example, prices in "restaurants and accommodation" are obtained from repeatedly asking a selected group of restaurants and hotels. Second, quality changes represent an ever-recurring challenge when measuring price changes. The price index is typically designed to capture the price movements in the same basket of goods over time. Prices for a good may change either because the price moves or because there are quality improvements. For these first two challenges, we rely on the data from Statistics Norway in our analysis. To the extent possible, Statistics Norway deals with these challenges according to the common European statistical framework (EUROSTAT).

Third, some sectors are partly or wholly government-regulated. For example, transport services are typically regulated by the municipality, and the public provides a large part of education and health services at no cost. We remove prices in sectors that are primarily government-regulated from our sample. This includes *044 Water supply and miscellaneous services relating to the dwelling*, *045 Electricity, gas and other fuels*, *061 Medical products, appliances and equipment*, *062 Out-patient services*, *073 Transport services*, *081 Postal services*, and *124 Social Protection*. Table A.1 in Appendix A details how we define COICOP codes as government-regulated, durables, non-durables, and services. Care should be taken when comparing our results to results in countries where costs related to health and education constitute a significant fraction of expenditures.

Our final price sample comprises 28 sub-indices, covering approximately 83% of the Consumer Price Index between January 2001 and December 2018. When estimating impulse responses of the policy rate, aggregate price indices, and national accounts data (including wages and hours), our sample spans from January 1995 to December 2018.

Monetary policy. We are concerned with how interest rate changes by the central bank affect prices. To represent the interest rate, we use the key policy rate at the end of the month. Because the central bank responds to economic conditions when setting the interest rate, interest rate changes are endogenous. To address this endogeneity issue, we use the monetary policy shocks from Holm, Paul, and Tischbirek (2021) as instruments for unexpected monetary policy innovations. Holm, Paul, and Tischbirek (2021) construct monetary policy shocks following the approach in Romer and Romer (2004) as the change

in the interest rate that is unrelated to Norges Bank's forecasts about output and inflation. The original series spans from 1994 to 2018 and is constructed at the frequency of monetary policy meetings. We use the series at the monthly frequency by summing up all shocks within the month. We refer to Holm, Paul, and Tischbirek (2021) for the estimation of the shocks and the tests for the exogeneity of the shock series.



Notes: The figure displays the monetary policy shocks from Holm, Paul, and Tischbirek (2021).

Figure 1: Monetary policy shocks.

Figure 1 presents the monthly shock series. The main event is a significant contraction in 2002 (positive shocks), followed by a series of expansionary shocks in 2003 (negative shocks). Reassuringly, a committee of external experts evaluating Norges Bank criticized the interest rate decisions in 2002 and 2003 as policy mistakes, citing the 2002 rate as too contractionary and the 2003 rate as too expansionary (Bjørnland, Ekeli, Geraats, and Leitemo, 2004). For further discussion and documentation of the properties of this shock series, including the unpredictability of the shocks from past aggregate data and an explanation of the events that led to the large identified shocks, we refer to Holm, Paul, and Tischbirek (2021).

Variables. Besides the price indices from Statistics Norway, we use a number of other variables in the analysis. First, we use the averages within a month of the I-44 (import-weighted) exchange rate from Norges Bank.

Second, we use several variables from the firm balance sheets and income statements. Specifically, we use the long-term debt, cost components (total, wages, and materials), sales, and current assets (including inventories) and current liabilities from the firm's accounts. All variables are defined at the sectoral level (NACE) and then transformed to COICOP as described below. The debt-to-cost ratio is defined as the sum of long-term debt divided by the sum of total costs at the COICOP level. The net working capital to sales ratio is defined as current assets net of current liabilities divided by total sales at the COICOP level.

Third, we measure import exposure as the import content of household final consumption. We first compute the direct and indirect imported-input content of domestic production using the 2012 input-output table for Norway from the World Input-Output Database (WIOD) Timmer, Dietzenbacher, Los, Stehrer, and de Vries (2015), following the approach in Dhyne, Kikkawa, Mogstad, and Tintelnot (2023, Section II.D). Specifically, the import content of domestic production is defined as the sum of the direct import share of the sector and the import shares of its suppliers, weighted by the supplier sectors' input shares. Since household consumption also includes direct imports of final goods and services from foreign sectors, we then calculate the sector-specific import content of household final consumption as the sum of: (1) the imported-input content of the domestic sector, weighted by the share of household final consumption sourced domestically, and (2) the share of household final consumption sourced directly from the foreign sector. The import content measure is defined at the NACE level and transformed to COICOP using the bridge matrix described below.

Fourth, we use quarterly aggregate wages and hours from the national accounts when we estimate the impact of monetary policy on labor market outcomes.

Mapping from NACE to COICOP classifications. The firm-level and trade data are organized by production-side NACE sectors, whereas the price indices follow the consumption-side COICOP classification. We map the former to the latter using a bridge matrix developed for Norway by Cai and Vandyck (2020), which yields measures of debt, costs, current assets and liabilities, sales, and import content for each 3-digit COICOP price index. We describe the mapping in detail in Appendix A.

3 Empirical strategy

We estimate the effects of monetary policy on prices using instrumental variable local projections. We rely on a baseline specification to trace the response of aggregate and

individual prices (Section 4) and on an interaction specification to relate these responses to sector characteristics when we examine transmission channels (Section 5).

3.1 Baseline specification

We estimate the effect of monetary policy on prices using an instrumental variable local projection framework:

$$p_{i,t+h} - p_{i,t-1} = \alpha_{i,h} + \beta^r_{i,h,0}\Delta r_t + \sum_{s=1}^{36} \beta^r_{i,h,s}\Delta r_{t-s} + \sum_{s=1}^{11} \beta^p_{i,h,s}\Delta p_{i,t-s} + \beta_m + \varepsilon_{i,t,h}, \tag{1}$$

$$\Delta r_t = \delta_0 + \delta_1 Z_t + \sum_{s=1}^{36} \delta_{1,s}\Delta r_{t-s} + \delta_m + u_{i,t} \tag{2}$$

where p_i is the log price of sector i, Δr_t is the change in the nominal key policy rate from beginning until end of month t, Z_t is the monetary policy shock, $\alpha_{i,h}$ is a horizon-fixed effect for sector i, β_m and δ_m are month-fixed effects, and $\varepsilon_{i,t,h}$ and $u_{i,t}$ are error terms. We use the predicted interest rate change $\widehat{\Delta r_t}$ from equation (2) when we estimate equation (1). The specification includes three years of interest rate lags and one year of price change lags. When we estimate the system on aggregate data, the price controls are also included in the first-stage regression. When we estimate using quarterly data, we include the number of lags corresponding to the same time length as for the monthly controls. We use Newey and West (1987) standard errors when estimating the regression system using only time-series data and Driscoll and Kraay (1998) standard errors when estimating the system with disaggregated price index data. We weight the regressions by CPI expenditure shares in specifications using the disaggregated price-index panel.

3.2 Interaction specification

In several of the settings below, we estimate the association between the effect of monetary policy on prices and the variation in a variable X_i (e.g., import content, debt-to-total costs, or the net working capital-to-sales ratio). In these cases, we estimate the interaction effect between monetary policy and the variable X_i using the following instrumental variable

local projection framework:

$$p_{i,t+h} - p_{i,t-1} = \alpha_{i,h} + \beta^r_{i,h,0}\Delta r_t + \sum_{s=1}^{36} \beta^r_{i,h,s}\Delta r_{t-s} + \beta^{\text{int}}_{i,h}\Delta r_t \cdot X_i + \sum_{j=1}^{11} \beta^p_{i,h,j}\Delta p_{i,t-j} + \beta_m + \varepsilon_{i,t,h}, \quad (3)$$

$$\Delta r_t = \delta_0 + \delta_1 Z_t + \delta_2 Z_t \cdot X_i + \delta_3 X_i + \sum_{s=1}^{36} \delta_{1,s}\Delta r_{t-s} + \delta_m + u_{i,t}, \quad (4)$$

$$\Delta r_t \cdot X_i = \delta^{\text{int}}_0 + \delta^{\text{int}}_1 Z_t + \delta^{\text{int}}_2 Z_t \cdot X_i + \delta^{\text{int}}_3 X_i + \sum_{s=1}^{36} \delta^{\text{int}}_{1,s}\Delta r_{t-s} + \delta^{\text{int}}_m + u^{\text{int}}_{i,t} \quad (5)$$

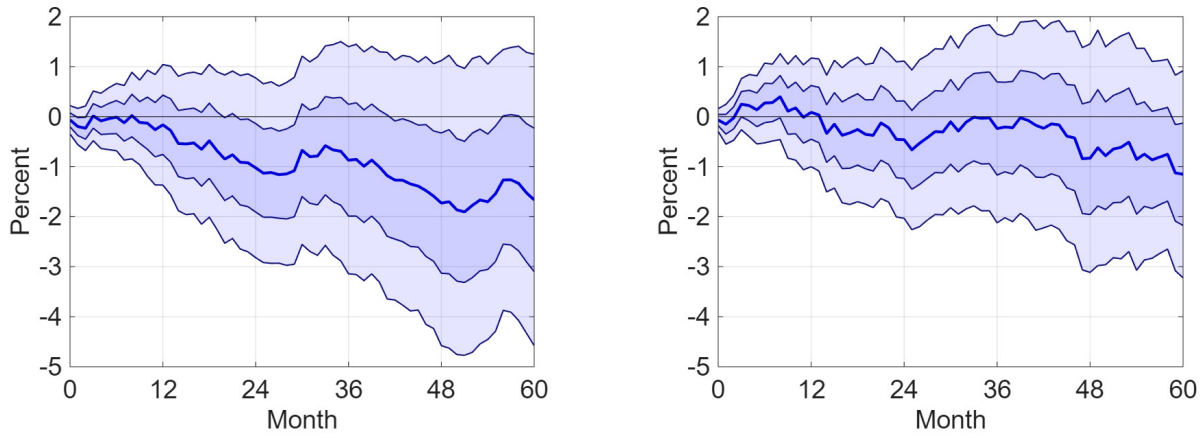
where p_i is the log price of sector i, Δr_t is the change in the nominal key policy rate from beginning until end of month t, X_i is the interaction variable of interest (constant for sector i), Z_t is the monetary policy shock, $\alpha_{i,h}$ is a horizon-fixed effect for sector i, β_m, δ_m, and δ^{int}_m are month-fixed effects, and $\varepsilon_{i,t,h}$, $u_{i,t}$, and $u^{\text{int}}_{i,t}$ are error terms. We use the predicted interest rate change $\widehat{\Delta r_t}$ and interaction term $\widehat{\Delta r_t \cdot X_i}$ from equations (4) and (5) when we estimate equation (3). As before, the specification includes three years of interest rate lags and one year of price change lags. We use Driscoll and Kraay (1998) standard errors when estimating the regression system using the disaggregated price-index panel, and weight the regressions by CPI expenditure shares.

4 Price responses to monetary policy

4.1 Aggregate and average price responses

The first result concerns the aggregate price index. Figure 2a presents the response of the consumer price index excluding electricity prices (CPI-AEL).[1] There are three main takeaways. First, aggregate prices tend to decline in response to a contractionary monetary policy shock. The effect is potentially sizeable, with a point estimate suggesting prices are almost 2 percent lower after five years in response to a 100-basis-point increase in interest rates. Second, the price response to monetary policy is delayed, gradually building up over time. Third, the price response is uncertain. While there is a tendency for prices to fall, the response is not statistically significant at any conventional level of significance. Figure 2b shows the CPI-weighted average price response estimated across the disaggregated price

[1] We use CPI-AEL, the Consumer Price Index excluding electricity prices, because it has existed since 1995. In contrast, CPI-ATE, the conventional core inflation index in Norway, has existed only since 2002. In Figure A.1 in Appendix B, we show the estimated response of the policy rate to the monetary policy shock estimated using equations (1) and (2). The policy rate increases by 100 basis points and then continues to rise before eventually reverting after about two years.



(a) Aggregate CPI-AEL. **(b)** Prices in the disaggregated sample.

Notes: The figures show the response of the CPI-AEL index and the CPI-weighted average response across the disaggregated price indices to a 100-basis-point interest rate increase, estimated using (1) and (2). 95 and 68 percent confidence bands are shown, computed using Newey and West (1987) standard errors in (a) and Driscoll and Kraay (1998) standard errors in (b).

Figure 2: Aggregate and average price responses to monetary policy.

indices in our sample. The response is similar to the aggregate CPI-AEL response, but somewhat smaller: the point estimate gradually builds up to around 1 percent but remains uncertain.

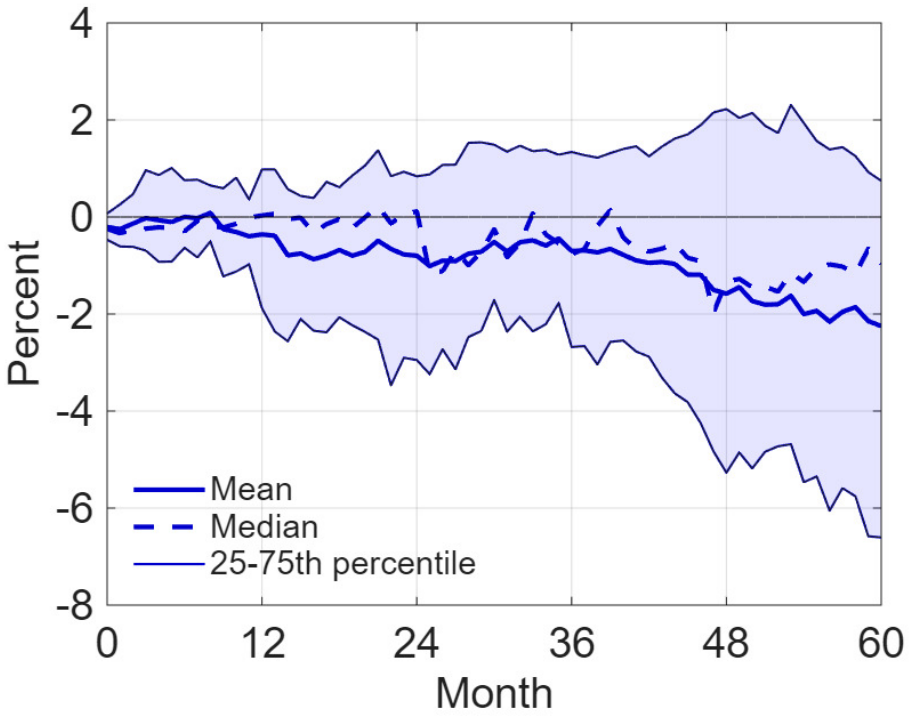
The estimated responses in Figure 2a differ from the price response estimated in Holm, Paul, and Tischbirek (2021). The primary reason for this difference is that we employ an instrumental variable setup in the current paper, whereas Holm, Paul, and Tischbirek (2021) estimates the reduced-form effect of the monetary policy shock. The estimation using the instrumental variable raises the standard errors somewhat. In Figure A.2 of Appendix B, we estimate a similar regression to that of Holm, Paul, and Tischbirek (2021) in our sample. The estimated coefficients are similar, but the standard errors are smaller.

4.2 Disaggregated price responses

The average price response we estimate in Figure 2b is the weighted average of underlying price responses and may hide significant dispersion. To explore this dispersion, we estimate how prices at the 3-digit COICOP level respond to monetary policy.

Figure 3 displays the mean, median, and the 25th and 75th percentiles of the estimated price responses when estimating equations (1) and (2) on individual price indices.[2] After

[2]When we compute the mean, median, 25th and 75th percentiles, we weight each statistic using CPI-



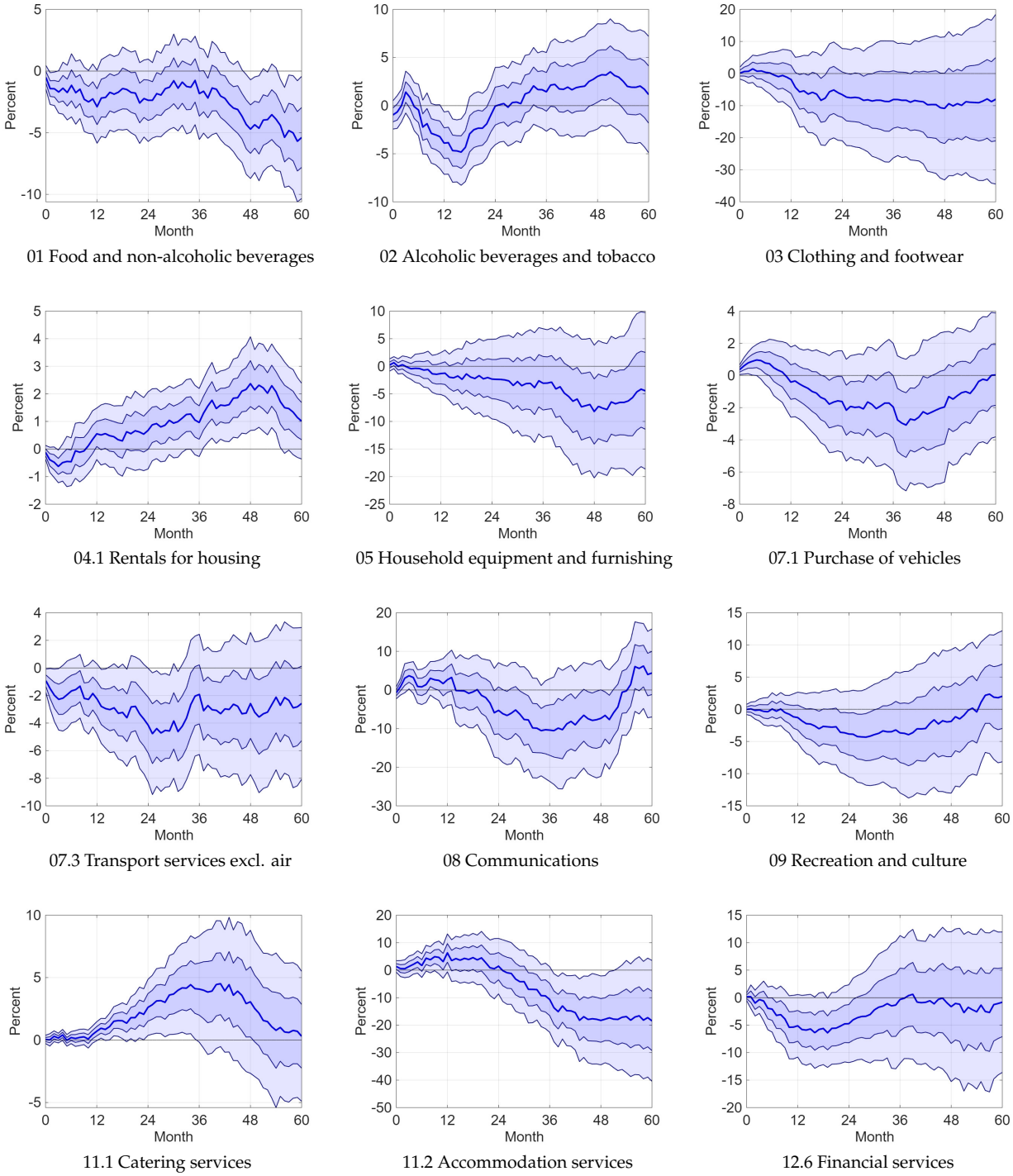
Notes: The figure shows the distribution of estimated individual price responses to a 100-basis-point interest rate increase, estimated using (1) and (2). All statistics are weighted using the CPI-weights.

Figure 3: The distribution of price responses to monetary policy.

five years the weighted median has declined by around 1 percent, close to the weighted-average price-index response in Figure 2b, while the weighted mean has fallen by around 2 percent, pulled down by a few sharply declining sectors. However, the mean and median responses hide significant heterogeneity. The shaded area in Figure 3 illustrates the dispersion in price responses, covering the 25th to 75th percentile of price responses. There is significant dispersion at all horizons. For example, after 60 months, the 25th percentile response is about -6 percent while the 75th percentile is around 1 percent.

Figure 4 further displays the price response of selected sectors. Some sectors exhibit significantly positive price responses to interest rate increases. For example, prices in *rentals for housing* rise by about 2.4 percent at their peak following a 100-basis-point interest rate increase. In contrast, several prices decrease in response to an interest rate hike, such as *food and non-alcoholic beverages* and *accommodation services*. Our next section examines the factors that may explain the variation in price responses, shedding light on the potential transmission channels at work.

weights, applying the code in Shrestha (2025).



Notes: The figure shows the response of selected price indices to a 100-basis-point interest rate increase. 95 and 68 percent confidence bands are shown, computed using Newey and West (1987) standard errors.

Figure 4: Disaggregated price responses to monetary policy within selected COICOP categories.

5 Monetary transmission channels

We now ask which mechanisms drive the price responses documented above. We examine three channels: the cost, aggregate demand, and exchange rate channels. Table 1 summarizes, for each channel, the mechanism through which it operates, the sign of the price response it predicts, and the variation in the data we use to identify it. We present the channels in order of how clearly the data speak to them, beginning with the cost channel, for which the evidence is sharpest, and ending with the exchange rate channel.

Channel	Mechanism	Predicted price response	Identifying variation
Cost	Higher interest rates raise firms' financing costs.	Higher prices, especially where interest expenses are a large share of costs.	Debt-to-cost and net-working-capital-to-sales ratios.
Aggregate demand	Higher interest rates reduce demand for consumption and investment.	Lower prices, and common across sectors	Durables vs. non-durables vs. services, wages and hours.
Exchange rate	Higher interest rates lead to a krone appreciation.	Lower prices, especially for import-intensive sectors.	Import content of consumption.

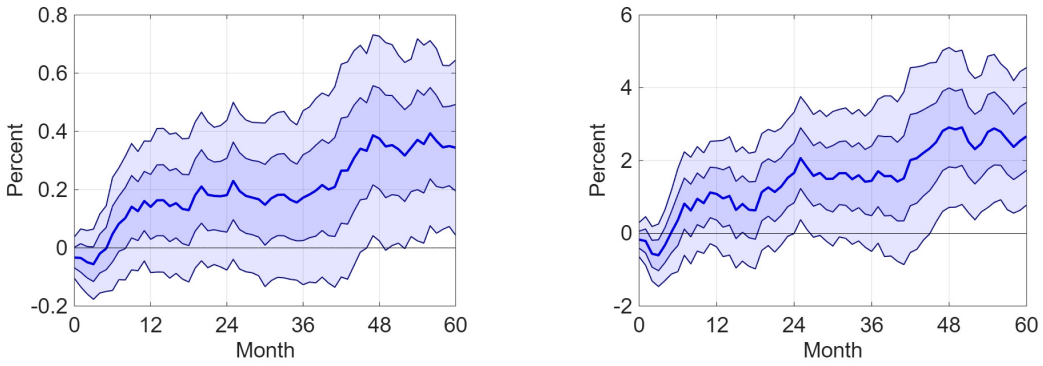
Table 1: Monetary transmission channels: mechanisms, predictions, and identification.

5.1 The cost channel

The first channel we examine is the cost channel of monetary policy (see, e.g., Barth and Ramey, 2001). An increase in the interest rate results in higher costs for firms, which may lead to higher prices. The cost channel thus operates in the opposite direction of the demand and exchange rate channels because a higher interest rate through the cost channel will result in higher prices.

The disaggregated price responses in Figure 4 already suggest that a cost channel may be responsible for some of the price increases in response to the interest rate increase. Specifically, prices for rentals for housing increase in response to an interest rate increase, a sector in which interest rate expenses are a relevant cost component.

To more rigorously explore the prevalence of a cost channel, we estimate how the price response to monetary policy varies with proxies for the extent to which interest rate expenses are a critical cost component in a sector. We examine two easily observable measures used in the prior literature: the long-term debt-to-total-cost ratio (Ravenna and Walsh, 2006) and net working capital as a share of sales (Barth and Ramey, 2001). The



(a) Debt as a share of total costs. **(b)** Net working capital as a share of sales.

Notes: The figures show the effect on consumer prices of a 100-basis-point interest rate increase interacted with the variables 'debt as a share of total costs' and 'net working capital as a share of sales,' estimated using (3), (4), and (5). 95 and 68 percent confidence bands are shown, computed using Driscoll and Kraay (1998) standard errors.

Figure 5: The association between the price response to monetary policy and debt as a share of total costs (a) and the net working capital as a share of sales (b).

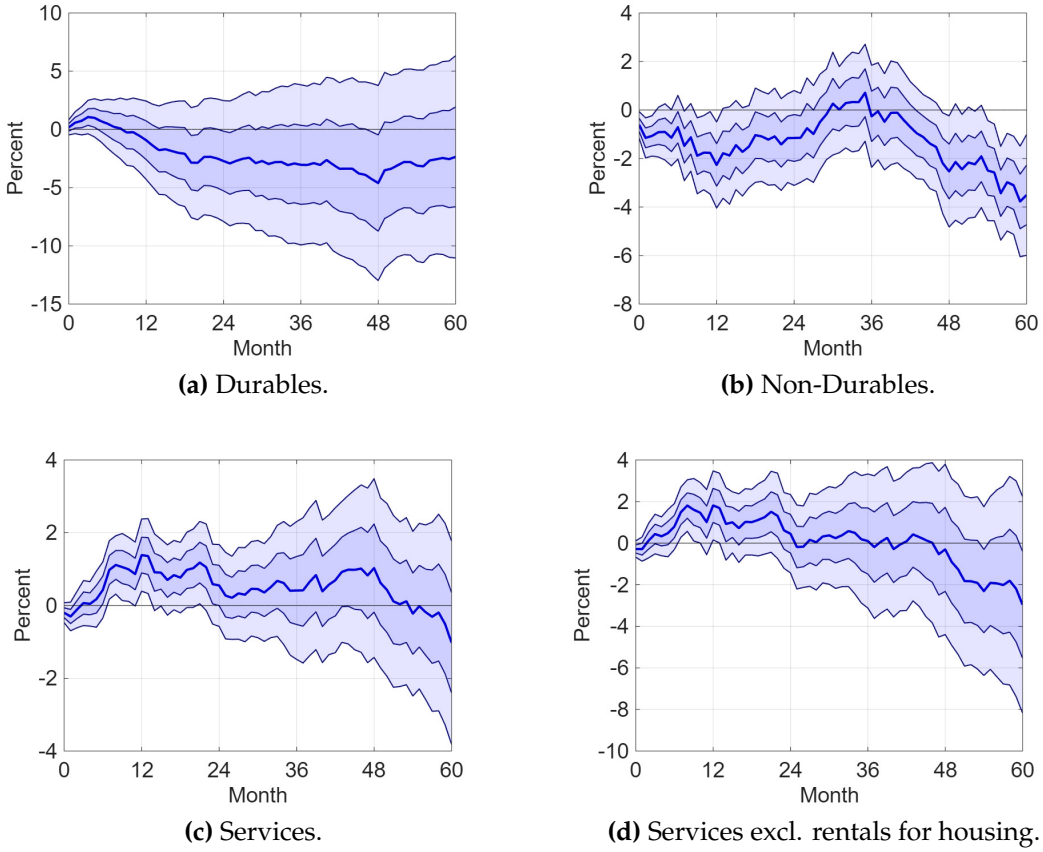
debt-to-total-cost ratio indicates the sensitivity of total costs to changes in the interest rate. Similarly, a high net working capital relative to sales indicates that the firm relies heavily on working capital for its day-to-day operations, and thus is concerned about the opportunity cost of this working capital.

Figures 5a and 5b display the estimated interaction coefficients when estimating equations (3), (4), and (5) with the debt-to-total-cost and the net-working-capital-to-sales ratios. For both ratios, we estimate a positive effect that gradually builds up and is statistically significant in years 4 and 5. Our results thus suggest that sectors with higher debt-to-total-cost or net working capital tend to raise prices more (or lower them less) in response to higher interest rates. The two interaction effects are also similar in magnitude when scaled by the variable's spread. Moving from a low- to a high-exposure sector (0 to 8 for debt-to-costs and from around 0 to 0.9 for working-capital-to-sales) is associated with about a 2.5 percentage-point change in the price response to monetary policy. Rentals for housing are a high-exposure sector by both measures, and important to explain the results.

5.2 The aggregate demand channel

The second channel we consider is the aggregate demand channel: in response to an interest rate increase, households and firms reduce their demand for consumption and

investment, which may lead to lower prices.



(a) Durables. **(b)** Non-Durables.

(c) Services. **(d)** Services excl. rentals for housing.

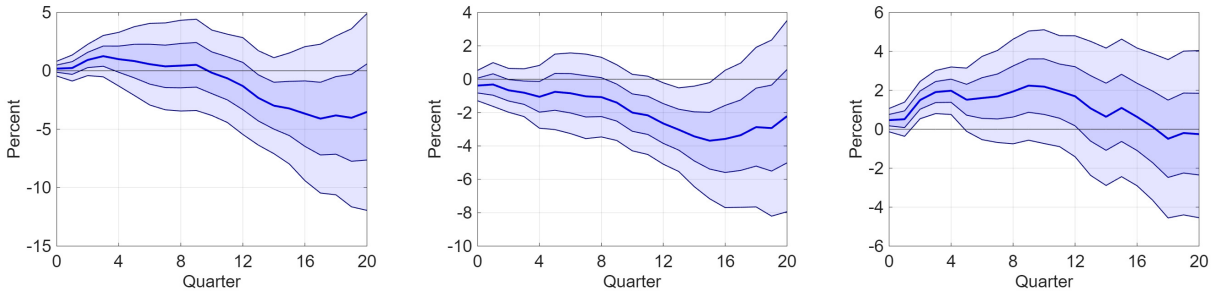
Notes: The figures show the average effect on prices of durables, non-durables, services, and services excluding housing to a 100-basis-point interest rate increase, estimated using (1) and (2). 95 and 68 percent confidence bands are shown, computed using Driscoll and Kraay (1998) standard errors.

Figure 6: Price responses by consumption categories.

The aggregate price response in Figure 2 and the distribution of price responses in Figure 3 both reveal a common pattern where prices gradually decline, pointing to an aggregate demand channel. However, the lack of statistical significance already indicates that this common channel must be relatively weak.

To understand the origin of this common response, we first categorize prices into three broad spending categories, as shown in Figure 6: durables, non-durables, and services. For durables, there is a tendency for prices to fall, but it is not statistically significant. For non-durables, prices decline significantly in response to an increase in interest rates. For services, the price response is relatively flat. If we exclude the imputed and actual rentals

for housing from services, there is a tendency for prices for services to also gradually fall in response to an increase in the interest rate.



(a) Total wages. **(b)** Total hours worked. **(c)** Wage per hour.

Notes: The figures show the effect on wages, hours worked, and wages per hour to a 100-basis-point interest rate increase, estimated using (1) and (2). 95 and 68 percent confidence bands are shown, computed using Newey and West (1987) standard errors.

Figure 7: Labor market responses to monetary policy.

A candidate explanation for the common pattern across non-durable goods and services is wage costs. The wage rate is an important input price, affecting prices across all sectors, especially those where wages are a large share of costs and can be passed through to prices. To investigate the role of wages in explaining the pattern, we estimate the total wage, total hours worked, and wage per hour responses to monetary policy using equations (1) and (2) with quarterly data from 1995 to 2018. Total wages decline by around 4% in year four in response to a 100-basis-point interest rate increase. However, while the total wage response may be informative, it could reflect either an increase in unemployment or a decline in actual wages. Indeed, in Figure 7b, we find that total hours worked decline by approximately 4% in year four in response to a 100-basis-point interest rate increase. Hence, the total wage response is driven almost entirely by the reduction in the number of hours worked.

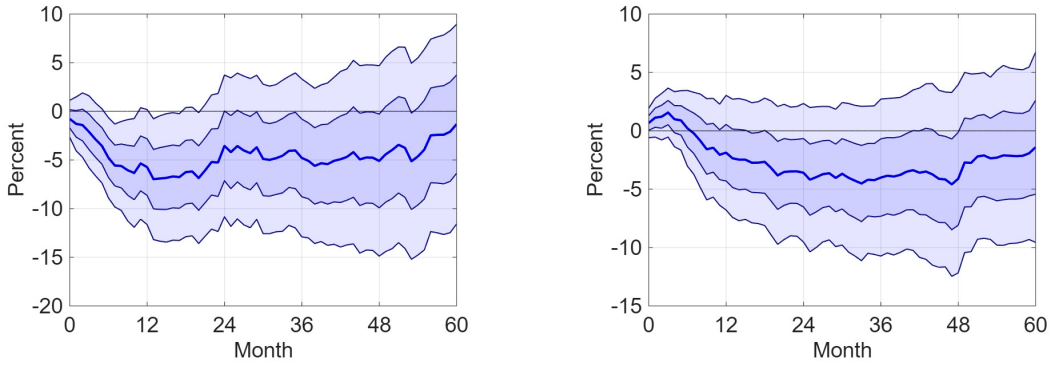
Figure 7c presents the estimated response of wages per hour in the national accounts to a 100-basis-point interest rate increase. The wage per hour, arguably a more precise measure of the wage costs (or the marginal costs) of existing firms, first increases, then gradually declines. A composition effect likely explains the initial increase in hourly wages because hours tend to fall disproportionately in low-wage occupations during a recession. However, even with such a composition effect, hourly wages eventually stop increasing and may even decline.

Notably, if there is a decline in wages per hour in Figure 7c, it is gradual. It builds

up over several years following monetary tightening, similar to the price responses. Hence, while we cannot confidently conclude that the aggregate demand channel plays a quantitatively significant role, we cannot rule out that it operates by reducing many prices with a substantial lag via the labor market.

5.3 The exchange rate channel

The third channel we consider is the exchange rate channel. When the central bank unexpectedly raises the nominal interest rate, several mechanisms suggest that the exchange rate may appreciate, which may eventually lead to lower prices for imported goods.



(a) I-44 **(b)** Import content.

Notes: Figure (a) shows the response of the I-44 to a 100-basis-point interest rate increase, estimated using (1) and (2). Figure (b) shows the effect on consumer prices of a 100-basis-point interest rate increase interacted with the import content, estimated using (3), (4), and (5). 95 and 68 percent confidence bands are shown, computed using Newey and West (1987) standard errors in (a), and using Driscoll and Kraay (1998) standard errors in (b).

Figure 8: Exchange-rate responses and price responses by import content to monetary policy.

To explore the potential importance of the exchange rate channel, we first estimate the effect of monetary policy on the I-44 exchange rate (an import-weighted composite exchange rate constructed by Norges Bank) using equations (1) and (2). Figure 8a presents the results. A 100-basis-point increase in the interest rate tends to appreciate the exchange rate (a negative response). The effect is quite sizable: the point estimate after one year is approximately a 6% exchange rate appreciation.

Even if the exchange rate appreciates in response to a higher interest rate, it does not necessarily imply that prices on imported goods will also decrease. We test the existence

of the exchange rate channel by estimating how the price response to monetary policy varies with the import content of the price index using the interaction effect framework in equations (3), (4), and (5). The measure combines imported inputs embodied in domestically produced consumption with directly imported final consumption goods and services.

Figure 8b displays the estimated interaction effect for the import content. Consistent with an exchange rate channel, the estimated interaction coefficient is negative: price indices with higher import content tend to decline more in response to a higher interest rate. However, the estimated coefficients are imprecise. Hence, while our results are qualitatively consistent with the presence of an exchange rate channel, we cannot confidently conclude that it is quantitatively important.

6 Conclusion

In this paper, we estimate the responses of disaggregated consumer prices to an increase in the interest rate. There is a tendency for prices to decline, but the response is delayed and uncertain. The price responses exhibit wide dispersion, with some prices falling significantly while others rise. We examine three transmission channels: the cost, aggregate demand, and exchange rate channels. The clearest evidence is for the cost channel: prices tend to rise in response to an interest rate increase in sectors with high long-term debt relative to total costs, most prominently *rentals for housing*. Our results are inconclusive regarding the aggregate demand and exchange rate channels, as these channels may or may not be quantitatively significant, but we cannot make confident claims.

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Online Appendix

A Appendix to Section 2

Mapping from NACE to COICOP classifications. The sectoral data are organized according to the NACE classification, which categorizes economic activities. NACE is closely aligned with the Classification of Products by Activity (CPA) classification in Eurostat, which categorizes the goods and services generated by these activities. Although firms may produce multiple goods or services that span different CPA categories, we consider this issue minor, given the relatively high level of aggregation employed in our analysis. We map data from the production side of the economy, as defined by CPA, to the consumption side, as determined by COICOP, using a bridge matrix developed for Norway by Cai and Vandyck (2020), which was constructed using a detailed Eurostat correspondence table and adjusted using a matrix procedure (RAS) to ensure consistency with the Norwegian national accounts. The procedure is further detailed in Cai and Rueda-Cantuche (2019). This process provides measures of debt, costs, current assets and liabilities, sales, and import content by 3-digit COICOP price indices.

Price Index	**Durables (D)**	**Non-Durables (ND)**	**Services (S)**
011 Food		✓	
012 Non-alcoholic beverages		✓	
021 Alcoholic beverages		✓	
022 Tobacco		✓	
031 Clothing	✓		
032 Footwear	✓		
041 Actual rentals for housing			✓
042 Imputed rentals for housing			✓
043 Maintenance and repair of the dwelling			✓
044 Water supply and miscellaneous services relating to the dwelling			✓
045 Electricity, gas and other fuels		✓	
051 Furniture and furnishings, carpets and other floor coverings	✓		
052 Household textiles	✓		
053 Household appliances	✓		
054 Glassware, tableware and household utensils	✓		
055 Tools and equipment for house and garden	✓		

Price Index	Durables (D)	Non-Durables (ND)	Services (S)
056 Goods and services for routine household maintenance		✓	
061 Medical products, appliances and equipment		✓	
062 Out-patient services			✓
071 Purchase of vehicles	✓		
072 Operation of personal transport equipment			✓
073 Transport services			✓
081 Postal services			✓
082 Telephone equipment	✓		
083 Telephone services			✓
091 Audio-visual, photographic and information processing equipment	✓		
092 Other major durables for recreation and culture	✓		
093 Other recreational items and equipment, gardens and pets		✓	
094 Recreational and cultural services			✓
095 Newspapers, books and stationery		✓	
096 Package holidays			✓
111 Restaurant services			✓
112 Accommodation services			✓
121 Personal care	✓		
123 Personal effects nec	✓		
124 Social protection			✓
125 Insurance			✓
126 Financial services nec			✓
127 Other services nec			✓

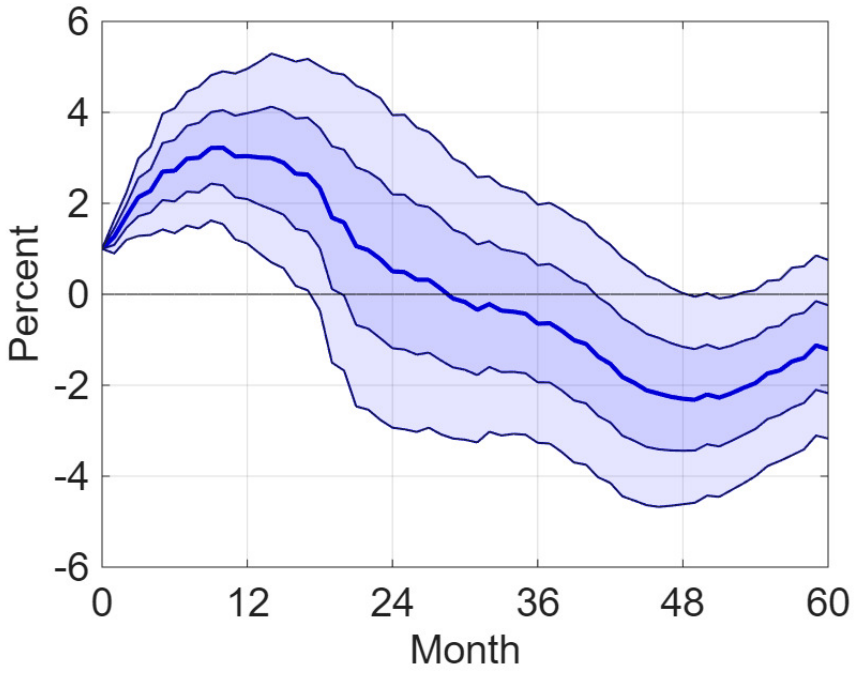
Notes: The table lists all 3-digit COICOP indices. The baseline sample excludes primarily government-regulated indices: 044, 045, 061, 062, 073, 081, and 124.

Table A.1: Price indexes (3-digit COICOP) and accompanying categories

B Appendix to Section 4

In Figure A.2, we estimate the effect of the monetary shocks on the aggregate price index using the following regression specification:

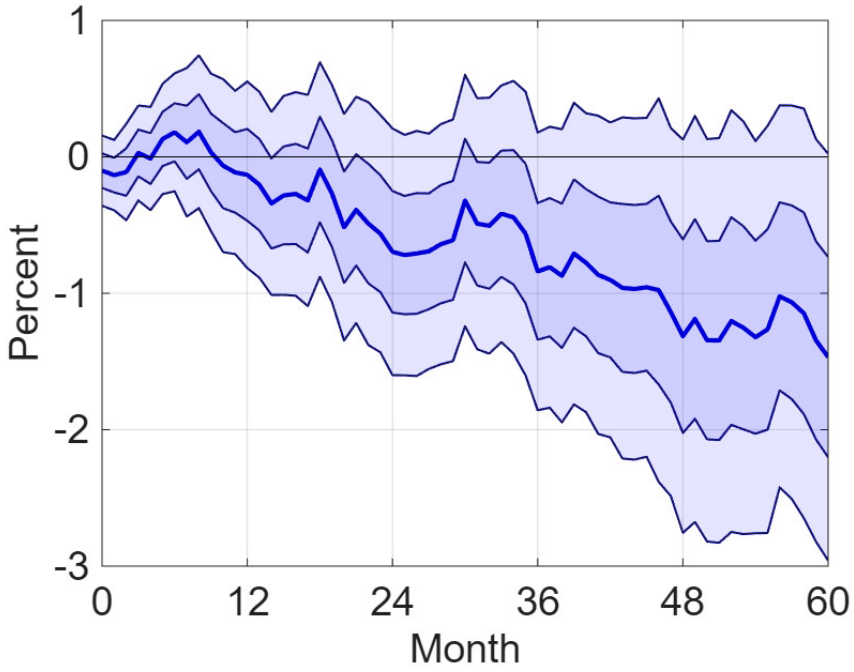
$$p_{t+h} - p_{t-1} = \alpha_{i,h} + \beta^r_{i,h,0} Z_t + \sum_{s=1}^{36} \beta^r_{i,h,s} Z_{t-s} + \beta_m + \varepsilon_{i,t,h}. \tag{A.1}$$



Notes: The figure displays the response of the policy rate to a 100-basis-point interest rate increase, estimated using (1) and (2). 95 and 68 confidence bands shown, computed using Newey and West (1987) standard errors.

Figure A.1: The policy rate response to monetary policy.

The main difference from the specification in the paper is that (A.1) estimates the reduced-form impact of the monetary policy shock (normalized to a 100-basis-point increase) on prices, not the effect of a 100-basis-point interest rate change as in the other specifications. Moreover, this specification does not include lags of the log price changes because they were not included in Holm, Paul, and Tischbirek (2021).



Notes: The figure displays the response of the policy rate to a 100-basis-point interest rate increase, estimated using (A.1). 95 and 68 confidence bands shown, computed using Newey and West (1987) standard errors.

Figure A.2: The aggregate price (CPI-AEL) response to monetary policy.