# Markups and Inflation in Oligopolistic Markets: Evidence from Wholesale Price Data*

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**Abstract**

How do market power and nominal price rigidity influence inflation dynamics? We formulate a tractable model of oligopolistic competition and sticky prices, and derive closed-form expressions for the pass-through of idiosyncratic and common cost shocks to firms' prices. Using unpublished micro data for Canadian wholesale firms, we estimate that idiosyncratic cost pass-through is incomplete and independent of the sector price stickiness, while common cost pass-through declines with price stickiness. The estimates imply a degree of strategic complementarity that lowers the slope of the New Keynesian Phillips curve by 30% in a one-sector model and by 64% in a multi-sector model.

**JEL classification codes:** D43, E31, L13, L81.

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# 1 Introduction

How does market power influence inflation dynamics and the transmission of monetary policy or exchange rate shocks? Standard New Keynesian models are not equipped to answer this question as they assume monopolistic competition among firms. Recent studies generalize the New Keynesian model to competition among a finite number of competing firms (Mongey, 2021; Wang and Werning, 2022). They demonstrate how strategic pricing complementarities among oligopolistic firms can dampen price adjustments and amplify real effects of monetary policy. Although much progress has been made in estimating the degree of strategic complementarities in price setting across firms, empirical studies have relied on frameworks based on models with monopolistic competition (Gopinath and Itskhoki, 2010*a*) or oligopolistic frameworks without nominal price rigidity (Auer and Schoenle, 2016; Amiti, Itskhoki and Konings, 2019). It is therefore an open empirical question how nominal rigidities and market power in oligopolistic markets *jointly* influence inflation dynamics.

In this paper, we answer this question by estimating the effects of nominal price rigidities and market power on pricing decisions of oligopolistically competitive wholesale trade firms. We formulate a tractable model of oligopolistic competition and sticky prices, and derive closed-form expressions for the pass-through of idiosyncratic and common cost shocks to firm markups. We then estimate how pass-through varies with measures of price stickiness and market power across and within sectors using detailed micro data for Canadian wholesale firms. We find strong evidence of the role of both price stickiness and market power in cost pass-through. Pass-through of idiosyncratic shocks is incomplete at 70% and is independent of the degree of sector price stickiness. Common cost pass-through declines with price stickiness: from nearly complete in flexible-price sectors to below 70% in sectors with the stickiest prices. Higher degrees of sector or firm market power lower the pass-through of each type of cost shock. These estimates imply a degree of strategic complementarity that lowers the slope of the New Keynesian Phillips curve (NKPC) by 30% in the one-sector model. Incorporating the observed positive correlation between price rigidity and market power into the multi-sector model lowers the slope by 64%.

While our model builds on recent literature of aggregated models with oligopolistic markets,[1] we make additional assumptions that capture the key features of the pricing behavior of wholesale firms, which enable the derivation of the closed-form pricing condition. Oligopolistic wholesalers (or *distributors*) buy a differentiated input good from suppliers and distribute it to final producers. The distributor's price and cost (i.e., the supplier's price) are sticky as in Calvo (1983), and their adjustments are synchronized, which we show is largely the case in the data. We derive a closed-form expression for the distributor's adjusted price as the sum of two terms: the pass-through of the idiosyncratic cost component and the pass-through of the common cost for all distributors in the sector.

The key prediction of the model is that price stickiness and market power jointly and *differentially* influence pass-through. In an oligopoly with flexible prices, firms adjust their markups in response to idiosyncratic cost changes to prevent their price from deviating too far from the prices of competitors. Since the common cost shock influences all prices equally, there is no incentive to adjust the markup. However, as sector prices become less flexible, common cost pass-through decreases, while idiosyncratic cost pass-through remains unaffected. Intuitively, knowing that after a common cost shock some competitors do not adjust their prices incentivizes the adjusting firm to temper its price changes by absorbing part of the cost shock into its markup. By contrast, idiosyncratic cost pass-through does not depend on the composition of adjusters and non-adjusters among competitors, and therefore it does not depend on price stickiness in the sector. On the flip side, if we hold the degree of price stickiness constant, increases in market power within an oligopoly decrease pass-through of both idiosyncratic and common cost shocks.

We test these predictions using unpublished price micro data from Canadian wholesalers used by Statistics Canada to produce the Wholesale Services Price Index (WSPI). The monthly data track about 14,000 individual products from 1,800 wholesale firms between January 2013 and December 2019. We assign "sectors" according to either the 4-digit North American Industry Classification

[1]As in Wang and Werning (2022), we have Calvo sticky prices under dynamic oligopolistic competition and, like Mongey (2021), we derive expressions for pass-through of both idiosyncratic and common shocks. Under flexible prices, our model nests static models of oligopolistic competition in Atkeson and Burstein (2008), Edmond, Midrigan and Xu (2015), and Amiti, Itskhoki and Konings (2019). Our model contributes to the growing literature that incorporates oligoplistic competition into macro models: Neiman (2011); Burstein, Carvalho and Grassi (2020); Baqaee, Farhi and Sangani (2021); Fujiwara and Matsuyama (2022); Höynck, Li and Zhang (2022); Alvarez, Lippi and Souganidis (2023); Ueda (2023); Ueda and Watanabe (2023).

System (NAICS4) or the 7-digit North American Product Classification System (NAPCS7). The distinguishing feature of the dataset is that for each wholesaler it provides the price at which it buys its products from suppliers ("purchase" price) and the price at which it sells these products to manufacturers or retailers ("selling" price). This allows us to construct accurate measures of nominal price rigidity for wholesalers' prices and costs. The ratio of selling to purchase price—the distributor's product margin—provides a direct measure of price markup, which is a standard measure of market power. We document substantial variation in measures of price stickiness and market power across and within sectors.

We first decompose the purchase price changes faced by wholesalers into common and idiosyncratic cost shocks using the approach in di Giovanni, Levchenko and Méjean (2014). The common cost shocks are derived by regressing monthly changes of log purchase prices on sector-month fixed effects, and the residuals define the idiosyncratic cost component. We then estimate the pass-through of these shocks to wholesalers' adjusted selling prices. Our empirical framework offers several advantages for estimating the joint contribution of price stickiness and market power to firm-product price adjustments: (1) it accounts for the effect of price stickiness on the degree of pass-through at monthly frequency; (2) it incorporates the observed margin as a reliable measure of market power; (3) it distinguishes pass-through of idiosyncratic and common cost shocks; and (4) it exploits variation in price stickiness and market power across and within sectors.

In line with theory, the estimated idiosyncratic cost pass-through is independent of price stickiness at sector and firm levels, and there is only a weak negative relationship at the firm-product level. On average, the pass-through of an idiosyncratic shock is about 70%, implying an underlying degree of strategic complementarity of $\varphi \approx 0.43$. By contrast, the pass-through of the common cost shock decreases with sector price stickiness, as our theory predicts. For a sector with flexible prices, the pass-through is close to 1, consistent with the findings in Amiti, Itskhoki and Konings (2019). As sector price stickiness rises, the pass-through declines quickly: for each additional 10 percentage point fall in price flexibility, the common cost pass-through falls by 10 percentage points for NAICS4 industries and 3 percentage points for NAPCS7 products. These results are primarily driven by sector-level price stickiness, rather than firm or product stickiness. Finally, a higher degree of sector or firm market power reduces the pass-through of both types of cost shocks.

These findings have important implications for inflation dynamics. Under oligopolistic competition, the slope of the NKPC in the one-sector model is reduced by a factor $\frac{1}{1+\varphi}$ relative to the slope under monopolistic competition. At the level of strategic complementarity implied by the estimated idiosyncratic cost pass-through, $\varphi = 0.43$, the slope of NKPC is reduced by 30%. This degree of strategic complementarity is substantial. For example, if markups were to increase by 10 percentage points over the next decade—the decennial rate of increase in market power over the last four decades documented in De Loecker, Eeckhout and Unger (2020)—the NKPC would flatten by an additional 12%.

When market power and nominal price rigidity vary across sectors, there is an additional flattening of the aggregate NKPC. The slope of the NKPC in the multi-sector model that matches heterogeneity in price stickiness and strategic complementarity across NAICSC4 (NAPCS7) sectors is only one-third (one-fourth) of the slope in the standard one-sector model without real rigidities. The additional amplification in the multi-sector model is due to the interaction of heterogeneity in price stickiness and strategic complementarity across firms and sectors (Carvalho, 2006; Nakamura and Steinsson, 2010). Right after a monetary shock, the aggregate price response is mostly driven by price adjustments in flexible-price sectors. As time passes, the distribution of price adjustments shifts toward sticky-price sectors, slowing the aggregate price response. We point out a novel dimension of this interaction mechanism, which stems from the positive correlation between nominal price rigidity and strategic complementarity across sectors that we observe in the data. Since sticky-price sectors tend to be more concentrated, price adjustments after the shock become increasingly smaller, further dampening the aggregate price response. Overall, our empirical estimates imply that the joint variation of price stickiness and market power across sectors more than doubles the propagation of nominal shocks obtained in models with identical sectors.

The contributions of this paper lie at the intersection of theoretical studies of how strategic interactions in oligopolistic markets influence inflation dynamics and empirical studies that aim to estimate the degree of strategic complementarities in the data. We build on insights from the first literature to develop a tractable model of oligopolistic competition in the wholesale sector, which gives testable predictions for how distributors' costs pass through to their prices. Although recent papers (Mongey, 2021; Wang and Werning, 2022) have highlighted some possible mechanisms linking strategic complementarity with the transmission of aggregate shocks, direct empirical evidence on these mechanisms remains scarce. Our paper takes advantage of the unique features of wholesale price data to estimate the combined effects of nominal price rigidity and market power on micro price adjustments, both across firm-products within a sector and across sectors. Our empirical evidence supports conclusions in this literature that models with a reasonable degree of oligopolistic competition provide significant amplification of the effects of nominal rigidities in standard New Keynesian models.[2]

In the context of the empirical literature, our framework generalizes two existing approaches. First, it extends flexible-price approaches to a setting with variation in the degree of nominal price rigidity across sectors. Amiti, Itskhoki and Konings (2019) estimate strategic complementarity under flexible prices where an instrumental variable is needed to generate exogenous movements in competitor prices. We do not use competitors' prices since only some of them adjust in response to shocks. Instead, we leverage our data and use cost measures to estimate the pass-through of cost shocks directly, avoiding the need to address endogeneity of competitors' prices to underlying costs. In a related paper, Gagliardone, Gertler, Lenzu and Tielens (2023) extend and enrich the annual dataset used by Amiti, Itskhoki and Konings (2019). They estimate a high pass-through of marginal cost into prices, showing that the implied NKPC slope is relatively high. We demonstrate, both theoretically and empirically, that the pass-through depends on variation in nominal price rigidity and market power across and within sectors. We show that accounting for heterogeneity in price stickiness and market power substantially lowers the slope of NKPC.

Furthermore, our framework generalizes monopolistically competitive sticky-price approaches to an oligopolistic environment with variation in the degree of market power across sectors. Gopinath and Itskhoki (2010*a*) find that goods with a higher frequency of price adjustments in the US import price micro data tend to have higher long-run exchange rate pass-through. They argue that

[2]Our paper also connects to a broader macro literature that emphasizes the role of the distribution margin in the transmission of domestic or international shocks (see, e.g., Burstein, Neves and Rebelo (2003); Burstein, Eichenbaum and Rebelo (2005); Corsetti and Dedola (2005); Goldberg and Campa (2010); Nakamura and Zerom (2010); Eichenbaum, Jaimovich and Rebelo (2011); Gopinath, Gourinchas, Hsieh and Li (2011); Gopinath and Itskhoki (2011); Goldberg and Hellerstein (2012); Berger, Faust, Rogers and Steverson (2012)). Our paper also relates to Ganapati (2024), which provides an in-depth study of the US wholesale sector using detailed administrative data. Ganapati (2024) documents that the share of manufactured goods distributed by wholesale firms has increased over time, representing roughly half of all goods by 2012, and that the sector exhibits clear patterns of firm heterogeneity and concentration.

monopolistically competitive sticky price models with variable markups and imported intermediate inputs can generate this relationship. Our empirical evidence highlights variation in market power as a key additional factor in the transmission of nominal shocks to the economy.

The paper proceeds as follows. Section 2 outlines the general equilibrium model with sectors of oligopolistically competitive distributors and derives the closed-form solution for optimal pass-through of distributors' supply costs to their adjusted prices. Section 3 summarizes the Canadian wholesale price micro data. Section 4 explains the decomposition of distributor cost changes into idiosyncratic and common components, presents our estimation method, and reports the estimation results. Section 5 distills the implications of the empirical estimates for inflation dynamics. Section 6 concludes.

## 2 Model with oligopolistic markets and sticky prices

This section outlines the model with oligopolistically competitive heterogeneous distributors. We derive a closed-form solution for optimal price adjustments by distributors that depend on changes in their own costs and costs of competitors. The pass-through of the idiosyncratic component of the firm's cost shock is incomplete due to strategic pricing complementarity arising endogenously under oligopolistic competition. The pass-through of the common component of the firm's cost shock is higher than the idiosyncratic cost pass-through, but it decreases with the degree of price stickiness in the sector. The degree of pass-through of both idiosyncratic and common cost shocks is decreasing in market power. We estimate these relationships in Section 4 using Canadian wholesale trade price micro data introduced in Section 3. In this section, we summarize the key assumptions and features of the model. We relegate the remaining details to Appendix B.

### 2.1 Model outline

**Households.** There are infinitely many identical households who derive utility from consuming a basket of $J$ final goods $c_{jt}$, $j = 1, ..., J$, and dis-utility from working $l_t$ hours, at wage $W_t$. We assume unit elasticity of substitution between sectors in aggregate consumption $c_t = \prod_j c_{jt}^{\alpha_j}$, with $\sum_j \alpha_j = 1$. Households with discount factor $\beta$ hold cash $M_t$, government bonds $B_t$ returning risk-free rate $R_t$, and obtain dividends $\Pi_t$.

Each household maximizes their lifetime utility

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left(\ln c_t - l_t\right),$$

subject to the sequence of budget constraints

$$M_t + B_t \leq W_t l_t + R_{t-1} B_{t-1} + M_{t-1} - \sum_{j=1}^{J} P_{jt-1} c_{jt-1} + \Pi_t,$$

cash-in-advance constraints for consumption spending $\sum_{j=1}^{J} P_{jt} c_{jt} \leq M_t$, and the lower-bound constraints on the risk-free rate $R_t \geq 1$.

The optimal consumption spending shares are constant: $\frac{P_{jt} c_{jt}}{P_t c_t} = \alpha_j$, where $P_t$ denotes the price of the bundle $c_t$. Assuming that the risk-free rate constraint is never binding, we obtain two standard first-order conditions. Total consumption is characterized by the Euler equation:

$$1 = \beta R_t \mathbb{E}_t \left[ \frac{P_t c_t}{P_{t+1} c_{t+1}} \right],$$

and the optimal labour supply satisfies

$$W_t = P_t c_t = M_t. \tag{1}$$

**Sector output and prices.** The production sector consists of producers who supply differentiated inputs to oligopolistically competitive distributors, which are then aggregated into sector outputs. As is standard in the literature, assumptions of log-linear utility and the Cobb-Douglas consumption aggregator lead to constant sector expenditure shares and one-to-one transmission of monetary policy change to the wage and total expenditure as in (1). This allows us to analyze price dynamics in a sector independently from prices in other sectors.

The output in sector $j$, $c_{jt}$, is aggregated over goods supplied by a finite number $N_j$ of distributors using a constant elasticity of substitution (CES) technology:

$$c_{jt} = \left[ \sum_{i=1}^{N_j} (c_{ijt})^{\frac{\theta-1}{\theta}} \right]^{\frac{\theta}{\theta-1}},$$

where $\theta$ is the within-sector elasticity of substitution, $c_{ijt}$ is the demand for distributor $i$'s output from the consumer's optimization problem,

$$c_{ijt} = \alpha_j \left( \frac{P_{ijt}}{P_{jt}} \right)^{-\theta} \frac{P_t}{P_{jt}} c_t,$$

and $P_{jt}$ is the price index for sector $j$:

$$P_{jt} \equiv \sum_{i=1}^{N_j} \left( P_{ijt} \frac{c_{ijt}}{c_{jt}} \right) = \left[ \sum_{i=1}^{N_j} (P_{ijt})^{1-\theta} \right]^{\frac{1}{1-\theta}}.$$

**Distributors.** Distributor $i$ in sector $j$ purchases input good $y_{ijt}$ from the producer of good $i$ at price $Q_{ijt}$, which it takes as given. The distributor uses linear technology to produce $c_{ijt}$ units of the good:

$$c_{ijt} = y_{ijt}.$$

The distributor's marginal cost is equal to the producer's price, $Q_{ijt}$.

Distributors' prices are sticky, where each period only a fraction $1 - \lambda_j$ of firms are able to change their prices, assigned according to a Poisson process as in Calvo (1983). Similarly to Mongey (2021), we assume that in period $t$ an adjusting firm observes marginal cost realizations for all firms, but it does not observe price adjustments of other firms until later in the period. All adjustments are simultaneous, so that no firm can respond to the new price chosen by another firm within the period. Under these assumptions, all adjusting firms have the same information for adjusting their prices and, therefore, they form identical expectations of current and future period variables. Expected values conditional on the information at the beginning of period $t$ are denoted by operator $\mathbb{E}_t$.

For the distributor adjusting its price in period $t$, the optimal reset price is

$$P_{ijt,t} = \frac{\mathbb{E}_t \sum_{\tau=0}^{\infty} (\beta\lambda_j)^{\tau} \vartheta_{ijt+\tau,t} c_{ijt+\tau,t}}{\mathbb{E}_t \sum_{\tau=0}^{\infty} (\beta\lambda_j)^{\tau} (\vartheta_{ijt+\tau,t} - 1) c_{ijt+\tau,t}/Q_{ijt+\tau}}, \tag{2}$$

where the second time subscript denotes the period of the last price adjustment; $\mathbb{E}_t\vartheta_{ijt+\tau,t}$ is the expected effective demand elasticity facing this distributor at $t+\tau,\ \tau = 0, 1, \ldots$,

$$\mathbb{E}_t\vartheta_{ijt+\tau,t} = \begin{cases} \mathbb{E}_t \left[\theta(1 - s_{ijt+\tau,t}) + s_{ijt+\tau,t}\right] & \text{(under Bertrand competition)} \\ \mathbb{E}_t \left[\frac{1}{\theta}(1 - s_{ijt+\tau,t}) + s_{ijt+\tau,t}\right]^{-1} & \text{(under Cournot competition)} \end{cases}, \tag{3}$$

where $\mathbb{E}_t s_{ijt+\tau,t}$ is the period-$t$ expected value of the market share of distributor $i$ in period $t+\tau$:

$$\mathbb{E}_t s_{ijt+\tau,t} \equiv \mathbb{E}_t \left[\frac{P_{ijt+\tau} c_{ijt+\tau}}{P_{jt+\tau} c_{jt+\tau}}\right] = \mathbb{E}_t \left[\frac{(P_{ijt+\tau})^{1-\theta}}{\sum_{i=1}^{N_j} (P_{ijt+\tau})^{1-\theta}}\right]. \tag{4}$$

**Producers.** Varieties are supplied to distributors by producers competing in monopolistically competitive markets. We assume a producer's price, $Q_{ijt}$, is sticky, changing according to a Poisson process with probability $1 - \lambda_j^p$: when the price adjusts, the producer resets it to the frictionless price $Q_{ijt}^*$, equal to the constant markup over its marginal cost, otherwise the price remains equal to the last period's price, $Q_{ijt-1}$.

## 2.2 Derivation of the closed-form solution for distributor's price changes

There are two challenges in solving (2) in closed form. First, the adjusting firm needs to take into account the effect of its price on the price of its competitors and vice versa. Second, it needs to form expectations about the dynamic path of the sector price.

**Strategic pricing complementarity.** Under log-linear approximation of (3) and (4), the firm's expected markup $\mathbb{E}_t\mu_{ijt+\tau,t} \equiv \mathbb{E}_t\frac{\vartheta_{ijt+\tau,t}}{\vartheta_{ijt+\tau,t}-1}$ depends on its reset price today and the expected sector price in the future:

$$\mathbb{E}_t\widehat{\mu}_{ijt+\tau,t} = -\varphi_{ij}\left[\widehat{P}_{ijt,t} - \mathbb{E}_t\widehat{P}_{jt+\tau}\right], \tag{5}$$

where hatted variables represent log-linear deviations of corresponding variables from steady state. Equation (5) shows that firms have an incentive to lower their markup as their price is pushed above the sector average price, known as strategic pricing complementarity.[3] It arises endogenously in oligopolistic markets and its strength is summarized by $\varphi_{ij}$:

$$\varphi_{ij} \equiv \begin{cases} \frac{s_{ij}}{[\theta(1-s_{ij})+s_{ij}](1-s_{ij})}(\theta-1) & \text{(under Bertrand competition)} \\ \frac{s_{ij}}{1-s_{ij}}(\theta-1) & \text{(under Cournot competition)} \end{cases} \tag{6}$$

In either case, $\varphi_{ij}$ is increasing in firm $i$'s market share, $s_{ij}$ (i.e., pricing complementarity is stronger with market power). As will become clear in the following discussions in this section and in Section 5, $\varphi_{ij}$ is a key statistic that governs the micro and macro price dynamics under oligopolistic competition.

Plugging (5) in the log-linearized pricing equation (2) and rearranging yields the reset price as the sum of its expected costs and expected sector prices:

$$\widehat{P}_{ijt,t} = \frac{1-\beta\lambda}{1+\varphi_{ij}} \sum_{\tau=0}^{\infty} (\beta\lambda_j)^{\tau} [\mathbb{E}_t \widehat{Q}_{ijt+\tau,t} + \varphi_{ij} \mathbb{E}_t \widehat{P}_{jt+\tau}]. \tag{7}$$

**Expected sector prices.** The expected average reset price in period $t$ is $\mathbb{E}_t \widehat{P}_{jt,t} \equiv \mathbb{E}_t \sum_i s_{ij} \widehat{P}_{ijt,t}$, which, after using (7), becomes

$$\mathbb{E}_t \widehat{P}_{jt,t} = \sum_i \left\{ s_{ij} \frac{(1-\beta\lambda_j)}{(1+\varphi_{ij})} \sum_{\tau=0}^{\infty} (\beta\lambda_j)^{\tau} [\mathbb{E}_t \widehat{Q}_{ijt+\tau,t} + \varphi_{ij} \mathbb{E}_t \widehat{P}_{jt+\tau}] \right\}. \tag{8}$$

Under Calvo pricing, the expected sector price can be written as follows:

$$\begin{aligned} \mathbb{E}_t \widehat{P}_{jt+\tau} &= \mathbb{E}_t \sum_i s_{ijt+\tau} \widehat{P}_{ijt+\tau} \\ &= (1-\lambda_j) \mathbb{E}_t \sum_i s_{ijt+\tau} \widehat{P}_{ijt+\tau,t+\tau} + \lambda_j \mathbb{E}_t \sum_i s_{ijt+\tau} \widehat{P}_{ijt+\tau-1} \\ &\approx (1-\lambda_j) \mathbb{E}_t \widehat{P}_{jt+\tau,t+\tau} + \lambda_j \mathbb{E}_t \widehat{P}_{jt+\tau-1}, \end{aligned} \tag{9}$$

[3] See, e.g., Kimball (1995), Atkeson and Burstein (2008), Nakamura and Steinsson (2013).

where the first equality is the definition of sector price, the second equality follows from Calvo pricing, and the third approximate equality follows from the fact that the effects of time variation in market shares $s_{ijt}$ on the sector price $P_{jt}$ are at most second order.[4]

Combining (8) and (9) gives the equation for expected sector inflation $\mathbb{E}_t\widehat{\pi}_{jt} \equiv \mathbb{E}_t(\widehat{P}_{jt} - \widehat{P}_{jt-1})$:

$$\mathbb{E}_t\widehat{\pi}_{jt} = \sum_i s_{ij} \frac{(1-\beta\lambda_j)(1-\lambda_j)}{\lambda_j\,(1+\varphi_{ij})} \mathbb{E}_t(\widehat{Q}_{ijt,t} - \widehat{P}_{jt}) + \beta\mathbb{E}_t\widehat{\pi}_{jt+1}. \tag{10}$$

Given expected cost processes $\{\mathbb{E}_t\widehat{Q}_{ijt+\tau,t}\}_{\tau=0}^{\infty}$, equation (10) fully characterizes the dynamics of expected sector prices $\{\mathbb{E}_t\widehat{P}_{jt+\tau}\}_{\tau=0}^{\infty}$. Note that (10) is the sector NKPC. It holds in expectations because the realized fraction of adjusting prices among finitely many firms varies over time even though the probability of price changes is constant due to Calvo pricing. We follow Wang and Werning (2022) and assume that the number of similar sectors is sufficiently large so that the variation in the sector fraction of adjusting prices does not have a first-order effect on the aggregate price.

Solving the expected sector prices from (10) together with the individual firms' price dynamics from (7) allows us to derive the expression for the distributor's optimal reset price in two steps. Proposition 1 derives the reset price condition assuming that costs $\widehat{Q}_{ijt}$ are flexible, i.e., $\widehat{Q}_{ijt} = \widehat{Q}^*_{ijt}$, and follow an AR(1) process. Proposition 2 then derives the reset price condition assuming that the costs $\widehat{Q}_{ijt}$ are sticky, which will form the basis for our empirical analysis.

**Proposition 1** *Assume the producer's price $\widehat{Q}_{ijt}$ is flexible and follows an AR(1) process with serial correlation $\rho_j$. The distributor's optimal reset price response to idiosyncratic and common*

[4] Intuitively, because market shares add up to 1, the effects of market winners on sector price are approximately offset by the effects of market losers if their average prices are similar. To illustrate, consider a shock $\delta$ that changes the market share of firm $i$ by $ds_i(\delta)$ and its price by $dP_i(\delta)$, and assume that firm prices are identical in steady state, $P_i = P$. The first-order effect of $\delta$ on the weighted sum of prices is $P\sum_i ds_i(\delta) + \sum_i s_i dP(\delta)$. Since market shares must add up to 1, $\sum_i ds_i(\delta) = 0$, variation in market shares has at most a second-order effect on the weighted mean.

*(average) cost changes, up to a first-order approximation, is given by*

$$\widehat{P}_{ijt,t} = \underbrace{\frac{1}{1+\varphi_{ij}}\frac{1-\beta\lambda_j}{1-\beta\lambda_j\rho_j}}_{\text{PT to idiosyncratic cost changes}}\left(\widehat{Q}_{ijt}-\widehat{Q}_{jt}\right)+\underbrace{\left[\frac{1}{1+\varphi_{ij}}+\frac{\varphi_{ij}}{1+\varphi_{ij}}\frac{\rho_j-\Lambda_j}{1-\beta\lambda_j\Lambda_j}\varkappa_j\right]\frac{1-\beta\lambda_j}{1-\beta\lambda_j\rho_j}}_{\text{PT to common (average) cost changes}}\widehat{Q}_{jt}, \tag{11}$$

*where $\widehat{Q}_{jt} \equiv \sum_i s_{ij}\widehat{Q}_{ijt}$ is the common (or average) cost change in sector $j$, $\Lambda_j \geq \lambda_j$ captures market power augmented price stickiness in sector $j$, and $\varkappa_j = 1$ when firms are symmetric ($s_{ij} = s_j$):*

$$\Lambda_j \equiv \frac{1}{2}\left[\lambda_j+\frac{1-b_j}{\beta\lambda_j}-\sqrt{\left(\lambda_j+\frac{1-b_j}{\beta\lambda_j}\right)^2-\frac{4}{\beta}}\right], \tag{12}$$

$$\varkappa_j \equiv \frac{a_j}{1-b_j+\lambda_j\left[\beta(\lambda_j-1)-1\right]}, \tag{13}$$

$$a_j \equiv \left(\sum_i \frac{(1-\beta\lambda_j)(1-\lambda_j)}{(1+\varphi_{ij})}s_{ij}\widehat{Q}_{ijt}\right)/\widehat{Q}_{jt},$$

$$b_j \equiv \sum_i s_{ij}\frac{\varphi_{ij}(1-\beta\lambda_j)(1-\lambda_j)}{(1+\varphi_{ij})}.$$

***Proof.*** *See Appendix B.1.*

Proposition 1 demonstrates that in a dynamic oligopolistic competition model with price stickiness, a firm's current cost and its competitors' current prices are no longer sufficient to characterize the firm's optimal price decision, as is the case in static oligopolistic competition models (Amiti, Itskhoki and Konings, 2019). This is because some of the competitors' current prices are not adjusted, and therefore do not reflect the optimal response to their cost. Rather, the adjusting firm recognizes that even if the competitor's cost shock is not reflected in the competitor's current price, it may influence the competitor's future price when it is adjusted. Proposition 1 shows that in the dynamic setting, the firm's idiosyncratic cost change $\widehat{Q}_{ijt} - \widehat{Q}_{jt}$ and the average cost change $\widehat{Q}_{jt}$ are sufficient to capture the optimal pricing decision.

Although Proposition 1 establishes the case under flexible producer prices, in the data producer prices are sticky and highly synchronized with distributor prices, as we show in Section 3 below.[5] Proposition 2 shows that the distributor's optimal reset price condition can be derived for the

[5]Infrequent adjustment and high synchronization of upstream and downstream prices have been documented for the retail sector in Eichenbaum, Jaimovich and Rebelo (2011) and Goldberg and Hellerstein (2012).

case with sticky costs under the assumption that the *timing* of distributor and producer price adjustments are synchronized.

**Proposition 2** *Let the timing of the producer and distributor price adjustments be determined by the identical Poisson process with the parameter* $\lambda_j = \lambda_j^p$. *The distributor's optimal reset price response to idiosyncratic and common cost shocks is*

$$\widehat{P}_{ijt,t} = \underbrace{\frac{1}{1+\varphi_{ij}}}_{\psi_{ij}} \left( \widehat{Q}^*_{ijt} - \widehat{Q}^*_{jt} \right) + \underbrace{\left[ \frac{1}{1+\varphi_{ij}} + \frac{\varphi_{ij}}{1+\varphi_{ij}} \left( \frac{\rho_j - \Lambda_j}{1-\beta\lambda_j\Lambda_j} \right) \varkappa_j \right]}_{\Psi_{ij}} \widehat{Q}^*_{jt}. \tag{14}$$

*where* $\psi_{ij}$ $(\Psi_{ij})$ *denotes idiosyncratic (common) cost pass-through.*

***Proof.*** *See Appendix B.1.*

With perfectly synchronized price and cost adjustments, the firm's cost is fixed over the duration of the price spell, and therefore, the adjusted price depends on the current cost. This implies that the pass-through of the idiosyncratic shock does not depend on the persistence of the shock $\rho_j$. The common cost pass-through still depends on $\rho_j$ because the adjusting firm forms expectations of competitors' future price adjustments given competitors' current costs.[6]

Figure 1 illustrates the key properties of the pass-through of these shocks to the distributor's reset price under Proposition 2, for the case with symmetric firms and random walk shocks ($\rho_j = 1$). The idiosyncratic cost pass-through (in solid blue), which we denote by $\psi_j \equiv \frac{1}{1+\varphi_j}$, decreases with the degree of strategic complementarity $\varphi_j$ for this firm, and it does not depend on the degree of price stickiness in the sector. The common cost pass-through (in dashed red), denoted by $\Psi_j \equiv \frac{1}{1+\varphi_j} + \frac{\varphi_j}{1+\varphi_j} \left( \frac{1-\Lambda_j}{1-\beta\lambda_j\Lambda_j} \right) \varkappa_j$, decreases with both strategic complementarity (albeit at a slower rate than $\psi_j$) and sector price stickiness.

Two special cases of equation (14) provide further intuition.

[6] At the aggregate level, the assumption of perfectly synchronized price and cost adjustments effectively collapses two layers of nominal rigidity—one at the producer level and the other at the distributor level—into a single layer, making our model more comparable to models with only one layer of nominal rigidity (e.g., Wang and Werning 2022 and Mongey 2021). See Appendix B.3 for more details.

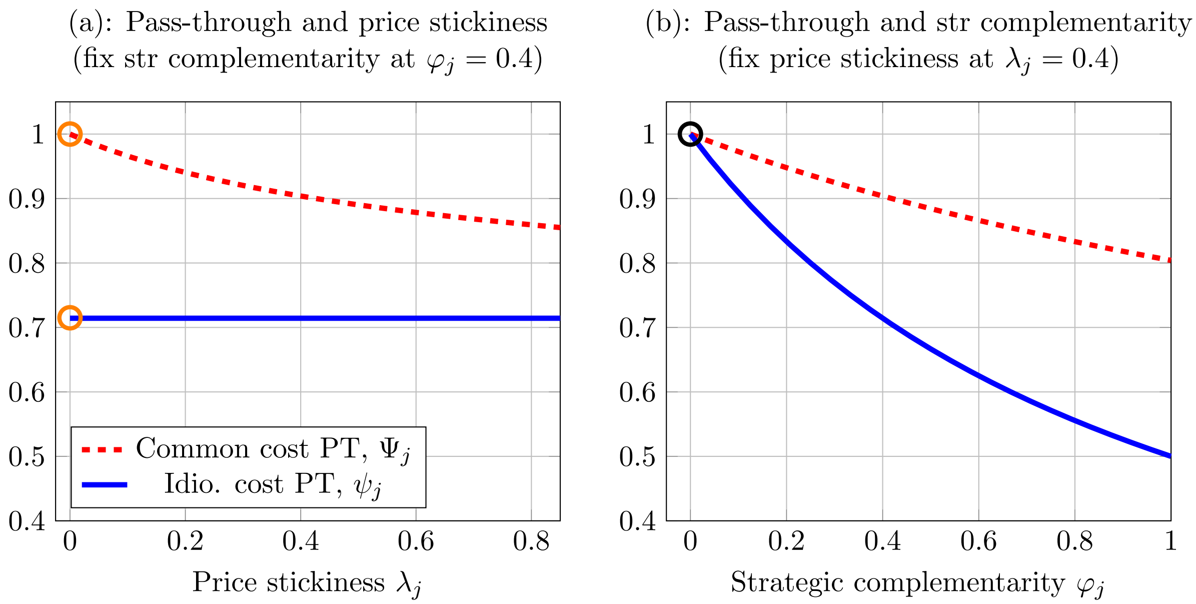


Figure 1: Idiosyncratic and common cost shock pass-through (symmetric firms)

Notes: The figure plots pass-through coefficients given by equation (14) for symmetric firms and random walk shocks ($\rho_j = 1$). Panel (a) demonstrates variation over $\lambda_j$ for $\varphi_j = 0.4$. Panel (b) shows variation over $\varphi_j$ for $\lambda_j = 0.4$. The orange circles in Panel (a) indicate special case of flexible prices ($\lambda_j = 0$). The black circle in Panel (b) indicates special case of monopolistic competition.

**Special case 1: Flexible prices, $\lambda_j = 0$:**

$$\widehat{P}_{ijt,t} = \frac{1}{1+\varphi_{ij}} \left( \widehat{Q}^*_{ijt} - \widehat{Q}^*_{jt} \right) + \left[ \frac{1}{1+\varphi_{ij}} + \frac{\varphi_{ij}}{1+\varphi_{ij}} \varkappa_j \right] \widehat{Q}^*_{jt}.$$

Under flexible prices, our model nests static models of oligopolistic competition in Atkeson and Burstein (2008), Edmond, Midrigan and Xu (2015), and Amiti, Itskhoki and Konings (2019) [AIK]. Similarly to AIK, when firms are symmetric ($s_{ij} = s_j$, $\varkappa_j = 1$), the common shock pass-through is complete ($\Psi_{ij} = 1$) and independent of the degree of market concentration in a sector or market power within a sector. Even in asymmetric cases, the common shock pass-through is close to one when cost shocks are small.[7] By contrast, a firm only partially responds to idiosyncratic cost shocks in an effort to prevent its price from deviating too far from competitors' prices, which would affect its market share. Such strategic motives are absent when all competing firms are hit by the common shock, resulting in complete pass-through.

[7] If $\widehat{Q}^*_{ijt} \to 0$, $\varkappa_j \to 1$ for any distribution of market power.

Our framework extends flexible-price cases to a more general setting with variation in the degree of nominal price rigidity across sectors. When prices are sticky, a common shock introduces relative price dispersion between adjusting and non-adjusting firms. Adjusting firms have an incentive to moderate their price responses to the common shock to limit deviation of their price from those of non-adjusting competitors. Given realization of the common shock, a higher degree of price stickiness means a higher number of non-adjusters, and hence a stronger motive for adjusters to mute their price deviation, implying lower common shock pass-through as shown in Figure 1(a). By contrast, the firm's own cost pass-through is not directly influenced by the composition of adjusters and non-adjusters. Hence, idiosyncratic cost pass-through does not depend on the degree of price stickiness.

**Special case 2: Monopolistic competition.** Taking the limit $s_{ijt} \to 0$ brings strategic complementarity to zero ($\varphi_{ij} \to 0$). The firm has no incentive to vary its markup in response to competitors' prices, and it fully passes through either idiosyncratic or common shocks ($\psi_{ij} \to 1$, $\Psi_{ij} \to 1$) by adjusting its price to changes in its cost: $\widehat{P}_{ijt,t} = \widehat{Q}_{ijt,t} = \widehat{Q}^*_{ijt}$.

Under oligopolistic competition, strategic pricing complementarity lowers both idiosyncratic and common shock pass-through (Figure 1(b)). As the degree of market power rises and there are fewer competitors, it becomes more costly for the firm to pass-through its own cost relative to the common cost, since the latter also affects its competitors. Therefore, as market power increases, idiosyncratic cost pass-through decreases faster than common cost pass-through.

**Non-CES demand.** In the benchmark model, strategic complementarities $\varphi_j$ arise from oligopolistic competition and the nested CES demand following Atkeson and Burstein (2008). It is well known that models with monopolistic competition and Kimball (1995) demand can also generate strategic complementarities due to extra curvature of the demand curve determined by a superelasticity parameter (Klenow and Willis, 2016). As we discuss in Appendix B.8, an alternative model with Kimball demand can be calibrated (via the superelasticity) to match the total effect of strategic complementarities on aggregate responses in the multi-sector oligopoly model. The caveat is that, in a multi-sector setting with Kimball demand, one would need to assume that the superelasticity varies systematically across sectors to capture heterogeneity in strategic complementarity. Our approach does not need to rely on the variation of preference parameters because sector-specific $\varphi_j$ are informed by estimated idiosyncratic pass-through coefficients $\psi_j$.

**Feedback versus strategic effects.** The equilibrium response of the distributor's reset price (14) reflects two types of strategic interactions, coined by Wang and Werning (2022) as the "feedback" and "strategic" effects. The feedback effect reflects the response to competitors' price adjustments over the adjusting firm's price horizon. The strategic effect reflects the responses of competing firms' future price adjustments to the firm's adjusted price. Our solution accounts for both effects.

As we demonstrate in detail in Appendix B.6, the strategic effect is quantitatively small. Following the approach in Wang and Werning (2022), we construct a counterfactual "naïve" model where a firm resets its price as a function of its competitors' prices in the *same* period, while still forming the correct expectations about future sector price dynamics. By construction, the difference in equilibrium price responses reflects the contributions of strategic effects. Similarly to Wang and Werning (2022), we find the difference to be quantitatively small, less than 1% for realistic calibrations. We also show that the log-linear approximation does not influence these results. In Appendix B.5, we numerically solve a nonlinear duopoly model and compare its equilibrium responses to the theoretical responses under the first-order approximation of our benchmark model. We find that the difference is quantitatively small (less than 4%).

## 3 Canadian wholesale trade price micro data

This paper uses unpublished survey-based price micro data used by Statistics Canada to construct the monthly WSPI. The survey's target population includes all statistical establishments primarily engaged in wholesaling, classified as NAICS wholesale trade (41).

Survey respondents are required to report product-specific figures for the average monthly purchase price (amount paid for the acquisition of a given product) and the average monthly selling price (amount received for selling the same product), whether the product was imported and, if imported, the product's country of origin. The data also include other price characteristics that could help inform observed price dynamics. These include establishment-level NAICS 5-digit (NAICS5) codes, product-specific NAPCS7 codes, and two variables that indicate the reason for a price change, for the purchase price and selling price, respectively, based on a predetermined list of reasons. Finally, the data also include information on the currency in which prices are reported.

The survey program is longitudinal in design, with the goal of continuously monitoring each product reported by a given establishment over several collection cycles. Respondents are instructed to report up to six products that are representative of their wholesaling activity, chosen based on either the products' contribution to annual sales or frequency of purchases.

The raw micro data used in this paper have not been cleaned prior to receiving the data, and none of the prices in our data are imputed. To the extent that is possible, we exclude outliers and anomalies from the raw micro data. For more information on the dataset and the data cleaning process, see Appendix A.1.

Our cleaned sample of monthly prices covers the period from January 2013 to December 2019. It has roughly 280,000 firm-product observations, including about 1,800 individual firms and 14,000 individual firm-products. The average firm-product variety has roughly 40 monthly observations, nearly all of which are consecutive. In terms of country of origin, the split across observations is 44% domestic, 32% US, and 25% other origins.

The dataset includes three sets of establishment-level weights that can be applied in regression analysis or summary statistics. The first is a "revenue weight," derived from establishment revenue data based on the Statistics Canada Business Register (BR) and industry gross margins based on the Annual Wholesale Trade Survey micro data.[8] The second is a "design weight," equal to the inverse of the firm's selection probability. This weight can be interpreted as the number of times that each sampled firm should be replicated to represent the entire population. Finally, a "sampling revenue weight" is equal to the product of the revenue weight and the design weight. It represents the relative importance of the establishment in the industry and is used to construct an index that is representative of the aggregate. When a wholesaler distributes multiple products, we divide the firm's weight equally across products. The sample and the weights are typically updated every 5 years. Unless otherwise noted, the weighted statistics or regressions in the paper use the sampling revenue weight to capture the economic importance of firms in the population.

[8] The BR is Statistics Canada's central repository of information on businesses and institutions operating in Canada. The sampling unit for the WSPI survey is the "establishment" level, and revenue weights are associated one-to-one with individual establishments.

### 3.1 Key features of the data

WSPI price micro data offer several key advantages for analyzing the interaction between nominal rigidities and market power. The literature has stressed that variable markups and strategic complementarities play only a limited role at the retail level, but an important role at the wholesale level (Nakamura and Zerom, 2010; Eichenbaum, Jaimovich and Rebelo, 2011; Gopinath, Gourinchas, Hsieh and Li, 2011; Gopinath and Itskhoki, 2011; Goldberg and Hellerstein, 2012). For each wholesaler, the dataset provides the price at which it buys its products from suppliers (purchase price) and the price at which it sells these products (selling price). Sectors are identified by an industry classification (NAICS4, 25 industries) or product classification (NAPCS7, 166 products). We use the selling price for the wholesaler product $i$ in sector $j$ in month $t$ to represent the distributor's output price $P_{ijt}$ in the model, and we use the purchase price to represent the producer's price $Q_{ijt}$ in the model. Since the data contain both purchase and selling prices, they provide accurate measures of nominal rigidity and markups at a firm-product level.

**Nominal rigidity.** We follow the literature by measuring nominal rigidity as the fraction of adjusting prices in a given month (Klenow and Kryvtsov, 2008; Nakamura and Steinsson, 2008). The average (mean) monthly fraction of selling price changes is defined as

$$Fr_j^P \equiv \frac{\sum_{i \in I_j} \sum_{t \in T_{ij}} \omega_{ij}^D \mathbb{1}\left[P_{ijt} \neq P_{ijt-1}\right]}{\sum_{i \in I_j} \sum_{t \in T_{ij}} \omega_{ij}^D}, \tag{15}$$

where $I_j$ denotes the set of firm-products in industry $j$; $T_{ij}$ denotes the set of months that firm-product $i$ in industry $j$ is surveyed; $\omega_{ij}^D$ represents the design weight of the firm (the inverse of the probability of being selected for the survey); and $\mathbb{1}\left[P_{ijt} \neq P_{ijt-1}\right]$ is an indicator of a selling price change for product-firm $i$. The fraction of adjusting purchase prices $Fr_j^Q$ is constructed similarly. We refer to $\lambda_j^P \equiv 1 - Fr_j^P$ ($\lambda_j^Q \equiv 1 - Fr_j^Q$) as selling (purchase) *price stickiness* in sector $j$.

The average monthly fraction of price changes is roughly 0.55 for selling prices and 0.50 for purchase prices. Figure 2 depicts the average fractions for each 3-digit NAICS industry (NAICS3). The monthly fraction of price changes varies significantly across industries: from 0.33 in the "Motor vehicle and motor vehicle parts and accessories merchant wholesalers" industry to 0.97 in the "Petroleum and petroleum products merchant wholesalers" industry.

Nominal price rigidity across sectors and products is highly correlated for selling and purchase prices. Figure 3 provides the corresponding scatter plots for NAICS4 and NAPCS7 classifications. In both cases, the fitted slopes are 0.88 and highly significant with $R^2 = 0.95$.

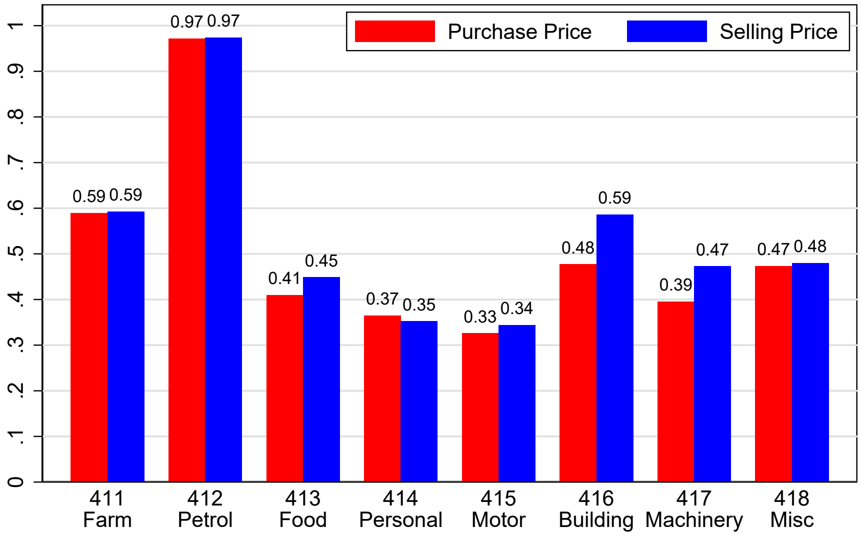


Figure 2: Average fraction of price changes by 3-digit NAICS wholesale industry

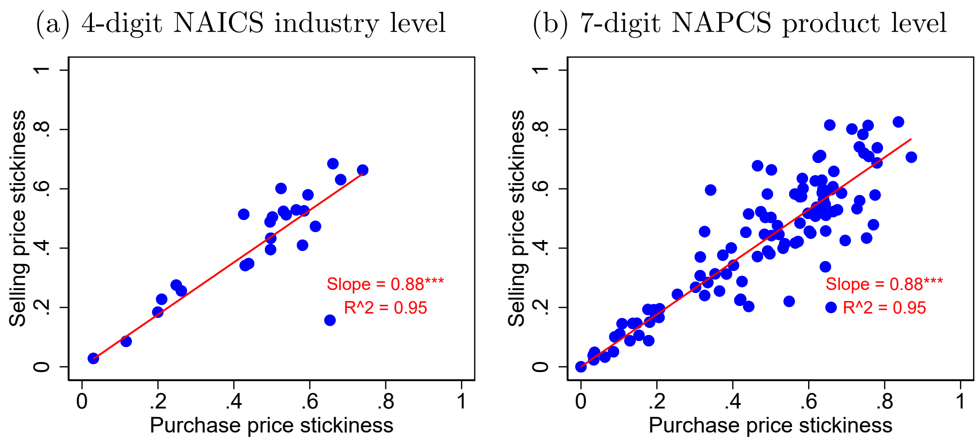


Figure 3: Selling and purchase price synchronization at the industry and product levels

Notes: Purchase (selling) price stickiness is given by $\lambda_j^P$ ($\lambda_j^Q$), where $j$ represents a sector according to NAICS4 industry classification (Panel (a)) or NAPCS7 product classification (Panel (b)).

This evidence suggests that selling price adjustments are highly synchronized with purchase price adjustments. Table 1 provides the firm-product-level (unweighted) frequency of the change of the selling price conditional on the change in the purchase price in the same month. Indeed, purchase and selling price changes are highly synchronized at the firm-product level. When a purchase price adjusts, there is a selling price change 86% of the time. And when the purchase price is unchanged from the previous month, the selling price is unchanged 75% of the time. The derivation of the closed-form solution (14) in Section 2 relies on the assumption of perfect synchronization between purchase and selling price changes, which, as we show here, is largely borne out in the data.

Table 1: Synchronization at the firm-product level

| | | Selling price change | |
|---|---|---|---|
| | | Yes | No |
| Purchase price change | Yes | 0.86 | 0.14 |
| | No | 0.25 | 0.75 |

Notes: Table provides unweighted means of an indicator of a selling price change/no change conditional on a purchase price change/no change in the same month.

**Markups.** Define the margin as the ratio of the firm-product selling price to the firm-product purchase price. Figure 4 provides the mean and standard deviation of (log) margins in our data for each NAICS3 wholesale sector. There is substantial variation in both the level and dispersion of product margins across sectors. The mean margin varies from 0.08 in the "Petroleum and petroleum products merchant wholesalers" industry to 0.53 in the "Personal and household goods" industry, and margin dispersion tends to be higher in industries with higher margin levels. The variation in dispersion presented in the figure indicates that firms have different degrees of market power within industries.

Since the firms represented in the data are wholesalers, they do not transform purchased goods before selling them to other firms. Therefore, the firm-product margin can be used as a reliable proxy for the firm-product markup. In our empirical analysis, we refer to the firm-product margin as *markup* and use it as a measure of the firm's market power.[9]

In practice, a wholesaler may incur other costs, such as wage payments to its staff, the cost of managing inventories, or the cost of maintaining its distribution facilities. We offer three arguments for why measurement issues do not significantly undermine our markup proxy. First, since wholesale

[9] A similar assumption is used in studies using retail price micro data, e.g., Eichenbaum, Jaimovich and Rebelo (2011), Gopinath, Gourinchas, Hsieh and Li (2011), and Anderson, Rebelo and Wong (2018).

firms do not transform the goods that they sell, nearly all of their direct costs come from costs of purchased goods rather than from labour or inventory costs.[10] Other indirect costs, such as the cost of maintaining distribution facilities, should be less variable over short horizons and are unlikely to contribute to the month-to-month marginal cost dynamics. Second, our empirical analysis uses firm-product fixed effects to control for variation in unobserved cost components across firms and products. Third, measurement error should render empirical estimates of idiosyncratic and common shock pass-through rates to be similar; however, our evidence strongly rejects their equality. All in all, we consider the firm-product margin as a reasonable markup proxy for the goals of this study (see Appendix A.6 for further discussion).

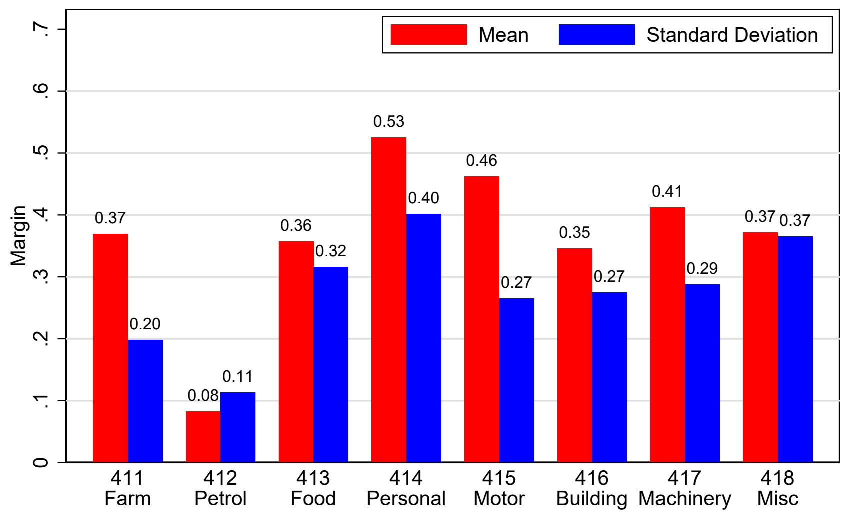


Figure 4: Average product margin by 3-digit NAICS wholesale industry

Notes: Margin is the log of the ratio of the selling and purchase price in the same month. Mean (standard deviation) is design-weighted mean (standard deviation) across all observations in the sector.

## 4 Estimation of price responses

In this section, we decompose the purchase price changes faced by wholesalers into common and idiosyncratic cost shocks and estimate the firms' pass-through of these two shocks, conditioning on a

[10]For example, Canadian industry statistics indicate that 96% of the wholesale industry's Cost of Goods Sold (COGS) is accounted for by "Purchases, materials and sub-contracts" and only 4% of COGS is accounted for by "Wages and benefits". By comparison, for the manufacturing sector this breakdown is 74% accounted for by "Purchases, materials and sub-contracts" and 26% accounted for by "Wages and benefits". See https://ised-isde.canada.ca/app/ixb/cis/search-recherche.

selling price change. We find strong support for our theoretical predictions: in oligopolistic markets, the pass-through of idiosyncratic shocks is incomplete and independent of the price stickiness of the industry, while the pass-through of common cost shocks decreases with the sector's price stickiness. Moreover, the pass-through of both idiosyncratic and common shocks is decreasing in market power.

In our baseline analysis, we define a sector as an industry at the NAICS4 level. As a robustness check, we define a sector at the product level using NAPCS7 product classification. In the data, each establishment may report multiple products. We treat each product as a separate entity and use $i$ to label firm-product pairs.

## 4.1 Estimation strategy

In Section 2, we derived the closed-form relationship (14) between the distributor's selling price at the time of adjustment and idiosyncratic and common components of its purchase price at that time. Using wholesale price micro data, we estimate equation (14) in two steps. First, we decompose purchase price changes in a sector into idiosyncratic and common components using the fixed-effect approach in di Giovanni, Levchenko and Méjean (2014). We then estimate the selling price response to these two cost shock measures, conditioning on a selling price change.

In the first step, we decompose the monthly changes of log purchase prices, $\Delta \ln(Q_{ijt}) = \ln(Q_{ijt}) - \ln(Q_{ijt-1})$, into common and idiosyncratic components by estimating an unweighted fixed-effect OLS regression

$$\Delta \ln(Q_{ijt}) = \epsilon_{jt} + \epsilon_{ijt}, \tag{16}$$

where $\epsilon_{jt}$ are the sector-month fixed effects and $\epsilon_{ijt}$ is the residual. Estimated $\widehat{\epsilon}_{jt}$ captures the average change in the purchase prices of all firm-product pairs in sector $j$ in month $t$, referred to as the "common cost shock"; and $\widehat{\epsilon}_{ijt}$ captures the idiosyncratic change in the purchase price of firm-product $i$ in sector $j$ at month $t$, referred to as the "idiosyncratic cost shock."[11]

In the second step, we estimate the pass-through of these shocks to wholesalers' selling price

[11]Since $\Delta \ln(Q_{ijt}) = 0$ for purchase prices that do not adjust in period $t$, the empirical shocks $\widehat{\epsilon}_{jt}$ and $\widehat{\epsilon}_{ijt}$ are approximations of the theoretical shocks in (14). In Appendix B.7, we use model simulated data to show that estimation using empirical shocks $\widehat{\epsilon}_{jt}$ and $\widehat{\epsilon}_{ijt}$ yields accurate estimates of the theoretical pass-through coefficients.

conditional on adjustment ($\Delta \ln(P_{ijt}) \neq 0$):

$$\Delta \ln(P_{ijt}) = \underbrace{\left(\Psi_0 + \Psi_1\lambda_j + \Psi_2\lambda_{fj} + \Psi_3\lambda_{ij} + \Psi_4 D_j + \Psi_5 D_{ij}\right)}_{\text{common cost pass-through}} \cdot \widehat{\epsilon}_{jt} + \underbrace{\left(\psi_0 + \psi_1\lambda_j + \psi_2\lambda_{fj} + \psi_3\lambda_{ij} + \psi_4 D_j + \psi_5 D_{ij}\right)}_{\text{idiosyncratic cost pass-through}} \cdot \widehat{\epsilon}_{ijt} + FE_{ij} + \nu_{ijt}, \quad (17)$$

where $FE_{ij}$ are firm-product fixed effects that absorb time-invariant heterogeneity in price adjustments across firm-products, and $\nu_{ijt}$ is the residual term.

In (17), we allow the pass-through rates to vary with price stickiness across sectors and across firms and products within a sector. We implement these covariates via interactions of the shocks $\widehat{\epsilon}_{jt}$ and $\widehat{\epsilon}_{ijt}$ with three measures of price stickiness and two measures of market power. Price stickiness $\lambda_j$, $\lambda_{fj}$, $\lambda_{ij}$ is equal to 1 minus the average monthly fraction of adjusting prices at the sector, firm, or product level, respectively. We use the distributor's markup to proxy for its market power.[12] Dummy $D_j$ identifies the top quartile of the markup distribution across sectors, and dummy $D_{ij}$ defines the top quartile of the markup distribution across firms within sector $j$.[13] We estimate (17) with a panel fixed-effects regression using all observations with non-zero selling price changes.

Specification (17) offers several advantages in estimating the joint contribution of price stickiness and market power to firm-product price adjustments. First, it incorporates the effect of price stickiness on the degree of cost pass-through at monthly frequency. This feature of our analysis is enabled by detailed micro data for monthly prices and markups of heterogeneous distributors in concentrated markets. As a special case, (17) nests the pass-through under flexible prices, which allows us to cross-validate our results with those in Amiti, Itskhoki and Konings (2019), who used micro data at annual frequency at which most prices are flexible.

Second, it incorporates reliable measures of market power. The margin in the WSPI price micro data provides a direct measure of price markup, which is a standard measure of market power.

[12]According to most imperfect competition models, price markup is a suitable proxy for market power. This is the case in our model, where market power, summarized by strategic complementarity $\varphi_{ij}$, is linear in steady-state price markup $\mu_{ij} \equiv \frac{\vartheta_{ij}}{\vartheta_{ij}-1} = \frac{\theta}{\theta-1}\frac{1}{1-s_{ij}}$ for any given $\theta$: $\varphi_{ij} = \left(\frac{\theta-1}{\theta}\mu_{ij} - 1\right)(\theta - 1)$. For empirical analysis, we prefer markup as the measure of market power to an alternative standard measure based on the firm's share of the sector's sales revenue because we do not observe the entire population of firms in each sector; on the other hand, markups in our dataset are observed at the product level and monthly frequency.

[13]See Appendix A.3 for more details on the construction of these variables.

In addition, since in the data we observe distributor costs directly and these costs are plausibly exogenous to distributors' prices, we can estimate the theoretical relationship (11) directly by a panel regression using (17). Studies using observed competitor prices for pass-through estimation face an additional challenge of addressing endogeneity of competitors' prices to underlying costs.[14]

Third, it distinguishes the pass-through of idiosyncratic and common cost shocks. Our model demonstrates how price stickiness and market power jointly and *differentially* influence the pass-through of these shocks. Our empirical analysis bears out these relationships in the data and provides numeric estimates that we use in Section 5 to derive quantitative implications for inflation dynamics.

Fourth, it distinguishes price stickiness and market power for different levels of aggregation. Macro theories in Mongey (2021), Wang and Werning (2022), and our model equation (14) demonstrate that the combined effects of nominal price rigidity and market power on micro price adjustments vary across firm-products within a sector and across sectors. Detailed coverage of the population of firm-products and sectors in our wholesale price data enables us to conduct adequate empirical analysis of these effects.

## 4.2 Estimation results by sector

We first estimate (17) separately for each of the NAICS4 industries and NAPCS7 products, i.e., we exploit variation within but not across sectors. Figure 5 provides scatter plots of the estimated pass-through coefficients against price stickiness and the average markup of the NAICS4 sector (NAPCS7 results are in Appendix A.4). The plots include the fitted line to summarize the relationship.

The results visualize a negative relationship of both common and idiosyncratic shock pass-through with sector price stickiness and market power for either industry or product classification. Together, price stickiness and average markup account for 53% (34%) of the variance in the common cost pass-through across NAICS4 (NAPCS7) sectors, and for 82% (65%) of the variance in the

[14] For example, Amiti, Itskhoki and Konings (2019) use proxies of competitors' costs as an instrument for competitors' prices. We discuss the differences and equivalence between our estimation approach and AIK in Appendix B.9.

idiosyncratic cost pass-through.[15]

The estimates for the common cost pass-through are in line with the model (Figure 1), which predict that pass-through declines with price stickiness and market power across sectors.

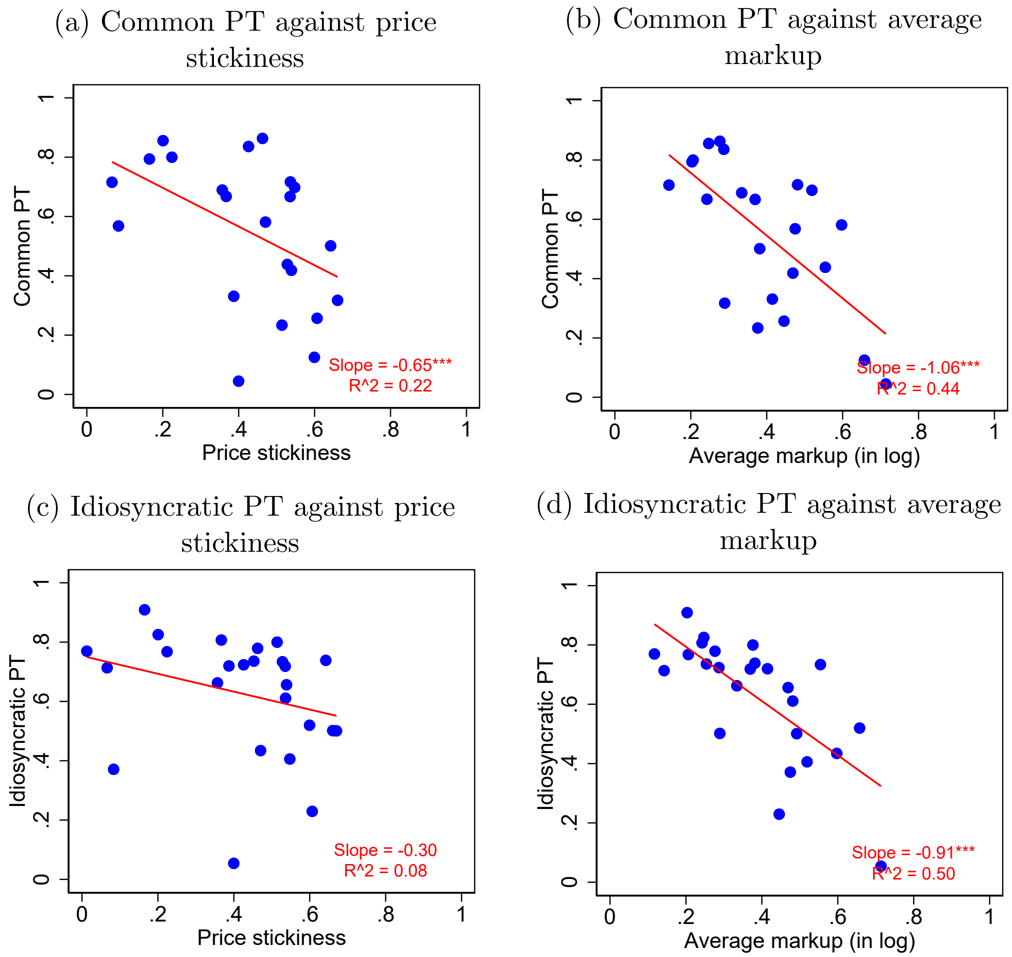


Figure 5: Estimates at the 4-digit NAICS wholesale industry level

Note: The figures plot the estimated selling price pass-through to common and idiosyncratic cost shocks against the average price stickiness and markup measured at the NAICS4 industry level. Specifically, we estimate $\Delta \ln(P_{ijt}) = \Psi_j \epsilon_{jt}^{Est} + \psi_j \epsilon_{ijt}^{Est} + FE_{ij} + \nu_{ijt}$ separately for each industry. For this graphical presentation, we have included only the industries with estimated pass-through rates in the range of $[-0.1, 1.1]$. The red line in each figure represents the fitted line obtained by regressing the estimated coefficients ($\Psi_j^{Est}$, $\psi_j^{Est}$) on the price stickiness $\lambda_j$ or the average markup $\mu_j$. The slope and the $R^2$ of the fitted line are reported in the bottom right corner of each figure.

Estimates for idiosyncratic cost pass-through are less clearly aligned with the model. Although pass-through significantly decreases with the average markup, the slope is not steeper than the

[15]The contribution of each variable is calculated as $|Cov(x_j, y_j)/Var(y_j)|$, where $y_j \in \{\Psi_j, \psi_j\}$ and $x_j \in \{\lambda_j, \mu_j\}$. Appendix A.5 provides detailed results.

slope of the common cost pass-through, as predicted by the model. Although price stickiness has a weaker influence on the idiosyncratic cost pass-through than the common cost pass-through, it is only for NAICS4 sectors that the slope is not statistically different from zero, and it is negative and significant for NAPCS7 sectors.

However, the negative relationship between idiosyncratic cost pass-through and price stickiness can be explained by the correlation between price stickiness and market power *across* sectors. In Appendix A.3, we document that sectors with high average markup tend to have stickier prices, with a slope of roughly 2/3: increasing a sector's average log markup from 0.2 to 0.6 corresponds to an increase in monthly price stickiness from 0.30 to 0.57, raising the average price duration by roughly one month. To the extent that higher price stickiness reflects higher market power (as opposed to higher price stickiness *given* market power), the slope in panel (c) of Figure 5 would be flatter if we controlled for the negative effect of market power on the pass-through.

### 4.3 Estimation results for all sectors

To incorporate cross-sector correlation, we now estimate (17) for observations in all sectors. We focus on NAICS4 estimates to summarize the main results and briefly summarize the NAPCS7 results (see Appendix A.4 for details). Table 2 provides estimated pass-through coefficients that capture variation in price stickiness and market power both across and within NAICS4 sectors.

To set the background, column (1) in Table 2 provides the estimated average pass-through coefficients across all wholesale firms in our sample. The average idiosyncratic pass-through of 0.65 is below the average common cost pass-through of 0.82. The theory predicts that both sticky prices and market power imply lower common cost pass-through. In particular, since the common cost pass-through should be 1 under flexible prices, the fact that the common cost pass-through is below 1 suggests an independent effect of price stickiness. As we demonstrated in Section 2, the model with market power and flexible prices predicts full pass-through of the common cost shock. Amiti, Itskhoki and Konings (2019)'s estimates imply that the average pass-through of a common shock is close to complete in their annual micro data, i.e., when prices are close to flexible. Our results validate the theoretical prediction that at higher frequencies the average common cost pass-through is incomplete due to infrequent price adjustments under oligopolistic competition.

Table 2: Pass-through estimates, 4-digit NAICS wholesale industries

| | (1) | (2) | (3) | (4) | (5) | (6) |
|---|---|---|---|---|---|---|
| Common cost | 0.82*** | 1.01***† | 1.00***† | 1.00***† | 1.08***† | 1.05***† |
| | (0.089) | (0.107) | (0.107) | (0.107) | (0.11) | (0.054) |
| Idio. cost | 0.65*** | 0.72*** | 0.72*** | 0.72*** | 0.75*** | 0.88*** |
| | (0.028) | (0.066) | (0.066) | (0.066) | (0.056) | (0.037) |
| Common cost × Sector stickiness | | -1.16*** | -1.02*** | -1.00*** | -0.96** | -0.70** |
| | | (0.31) | (0.304) | (0.3) | (0.338) | (0.251) |
| Idio. cost × Sector stickiness | | -0.18 | -0.13 | -0.13 | 0.03 | -0.04 |
| | | (0.148) | (0.156) | (0.154) | (0.132) | (0.097) |
| Common cost × Firm stickiness | | | -0.20 | | | |
| | | | (0.284) | | | |
| Idio. cost × Firm stickiness | | | -0.15 | | | |
| | | | (0.082) | | | |
| Common cost × Firm-product stickiness | | | | -0.20 | | |
| | | | | (0.256) | | |
| Idio. cost × Firm-product stickiness | | | | -0.18* | | |
| | | | | (0.078) | | |
| Common cost × High-markup industry | | | | | -0.29** | -0.29** |
| | | | | | (0.106) | (0.095) |
| Idio. cost × High-markup industry | | | | | -0.25*** | -0.24*** |
| | | | | | (0.046) | (0.042) |
| Common cost × High-markup firm | | | | | | -0.05 |
| | | | | | | (0.186) |
| Idio. cost × High-markup firm | | | | | | -0.33*** |
| | | | | | | (0.041) |
| Observations | 136,085 | 136,085 | 136,085 | 136,085 | 136,085 | 136,085 |
| Firm-product fixed effects | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| $R^2$ | 0.49 | 0.49 | 0.49 | 0.49 | 0.5 | 0.52 |

Notes: This table presents estimates for pass-through of common shocks and idiosyncratic shocks, interacted with indicators of sector/firm/firm-product stickiness and high sector/firm markups. The dependent variable is the firm-product selling price. Estimates are based on monthly price data, are weighted using sampling revenue weights, and are conditional on selling price adjustment (cases where the selling price is unchanged between periods are excluded). Common costs are identified via a first-stage regression of the firm-product purchase price on a sector-time fixed effect, where sector is defined as the firm's NAICS4 industry. Idiosyncratic shocks are defined as the residual of this first-stage regression. Standard errors are clustered at the firm level. ***, **, or * indicate the coefficient is statistically different from zero at the 1, 5, or 10 percent significance levels respectively, whereas † indicates the coefficient is not statistically different from one at the 1 percent significance level.

In the remaining regressions, reported in columns (2) through (6), we incorporate the interaction of common and idiosyncratic shocks with price stickiness across sectors. Furthermore, regressions reported in columns (3) and (4) include interactions with firm and firm-product price stickiness, and (5) and (6) add interactions with dummies for high-markup sectors and high-markup firms.

In line with the theory, the estimated idiosyncratic cost pass-through is independent of price stickiness at the sector and firm levels, and there is only a weak negative relationship at the firm-product level. On average, the pass-through of an idiosyncratic shock is about 70%, implying the underlying degree of strategic complementarity of $\varphi \approx 0.43$ in our model with *ex ante* identical sectors.

In contrast to idiosyncratic cost pass-through, the pass-through of the common cost shock decreases with sector price stickiness, as our theory predicts. For a sector with flexible prices, the pass-through is close to 1 (and not statistically different from 1), consistent with the findings in Amiti, Itskhoki and Konings (2019). As sector price stickiness rises, the pass-through declines quickly: for each additional 10 percentage point fall in price flexibility, the common cost pass-through falls by 10 percentage points for NAICS4 industries (and by 3 percentage points for NAPCS7 products). Our theory attributes this relationship to strategic pricing complementarity among firms in the sector. Intuitively, knowing its competitors' prices cannot accommodate the common shock (due to sticky prices), a firm uses its price change opportunity to adjust its markup, leading to an incomplete pass-through of the shock. The interaction terms with the common cost shock in columns (2), (3), and (4) confirm that this result is mostly driven by sector-level price stickiness rather than by firm or firm-product price stickiness.

For a given degree of sector price stickiness, both common and idiosyncratic pass-through decrease with market power of the sector (column 5 in Table 2), in line with the theory in Figure 1(b). Incorporating differences in market power within sectors (column 6) further lowers pass-through, especially for idiosyncratic shocks. When market power measures are included, the estimated effect of sector price stickiness on the common cost pass-through is somewhat more muted, reflecting the idea that some of the variation in price stickiness may be due to differences in market power across sectors and firms, as we discussed in Section 4.2.

All in all, the empirical results using NAICS4 classification corroborate all six predictions of the model for reset price pass-through: unit common cost pass-through and below-unit idiosyncratic cost pass-through under flexible prices; declining common cost pass-through and flat idiosyncratic cost pass-through for stickier sectors; declining pass-throughs with market power (and a steeper decline for idiosyncratic cost pass-through).

The estimation results are generally similar when sectors are defined according to the NAPCS7 product classification. Differences in the magnitude and significance of some estimates could reflect differences in the measurement of price stickiness and market power. In particular, since there is a smaller number of firm-products surveyed within each 7-digit NAPCS product classification than in the 4-digit NAICS industry classification, the measure of sector price stickiness may be less accurate due to noise stemming from adjustments of individual firms or products.

# 5 Implications for aggregate dynamics

In this section, we discuss the aggregate implications of our micro estimates and quantify the importance of firms' market power and its heterogeneity across sectors in amplifying the real effects of monetary policy. We start by characterizing sector and aggregate price and output dynamics in response to a 1% unanticipated permanent shock to the money supply in the benchmark setting.

**Proposition 3** *The sector and aggregate responses to a 1% unanticipated permanent monetary shock at $t = 0$ (i.e., $\widehat{M}_\tau = 1\ \forall\tau \geq 0$) are characterized as follows:*

*(i) The sector price, inflation and output responses are given by*

$$\widehat{P}_{j\tau} = 1 - \Lambda_j^{\tau+1}, \quad \widehat{\pi}_{j\tau} = (1 - \Lambda_j)\Lambda_j^\tau \quad \text{and} \quad \widehat{c}_{j\tau} = 1 - \widehat{P}_{j\tau} = \Lambda_j^{\tau+1} \qquad \forall\tau \geq 0, \tag{18}$$

*where $\Lambda_j \geq \lambda_j$ is the market power augmented price stickiness defined in (12).*

*(ii) The aggregate price response is given by*

$$\widehat{P}_\tau = \sum_j \alpha_j \widehat{P}_{j\tau} = (1 - \lambda)\widehat{P}_{\tau,\tau} + \lambda\widehat{P}_{\tau-1} - Cov_j\left[\lambda_j, \frac{1 - \Lambda_j}{1 - \lambda_j}\Lambda_j^\tau\right] \qquad \forall\tau \geq 0, \tag{19}$$

*where $\lambda \equiv \sum_j \alpha_j\lambda_j \equiv E_j(\lambda_j)$ is the average price stickiness in the economy and $\widehat{P}_{\tau,\tau} \equiv \sum_j \alpha_j \widehat{P}_{j\tau,\tau}$*

*is the average reset price.*

*(iii) The cumulative output response is given by*

$$\sum_j \alpha_j \sum_{\tau=0}^{\infty} \widehat{c}_{j\tau} = E_j \left[\frac{\lambda_j}{1-\lambda_j}\right] E_j \left[\frac{\Lambda_j(1-\lambda_j)}{\lambda_j(1-\Lambda_j)}\right] + Cov_j \left[\frac{\lambda_j}{1-\lambda_j}, \frac{\Lambda_j(1-\lambda_j)}{\lambda_j(1-\Lambda_j)}\right]. \tag{20}$$

***Proof.*** *See Appendix B.4.*

There are two key takeaways from Proposition 3. First, market power amplifies the sluggishness in sector price adjustments in response to a monetary shock and leads to a larger real impact in each sector. Since $\Lambda_j$ is an increasing function of market power $\varphi_j$, the sectors with higher market power increase their prices at a slower rate, as shown in (18).

Second, sector heterogeneity plays a role in further amplifying aggregate responses. Expression (19) shows that the aggregate price response can be decomposed as the average of adjusted and non-adjusted prices weighted by the average price stickiness, $(1-\lambda)\widehat{P}_{t+\tau,t+\tau} + \lambda\widehat{P}_{t+\tau-1}$, and an additional covariance term. In a standard Calvo model ($\varphi_j = 0$), the covariance term simplifies to $Cov_j \left[\lambda_j, \lambda_j^{\tau}\right] \geq 0$. As noted by Carvalho (2006), most price adjustments after the monetary shock are made by firms in more flexible sectors. As time passes, a larger proportion of prices that have yet to adjust are from stickier sectors, slowing the aggregate price adjustment. The covariance term captures this effect.

With market power ($\varphi_j \neq 0$), there are two additional effects. First, even when market power is homogeneous across sectors ($\varphi_j = \varphi$), $\Lambda_j > \lambda_j$ implies a larger covariance term. Strategic complementarities reduce the size of price adjustments, amplifying the effect of heterogeneity in price stickiness. A similar effect was emphasized by Carvalho (2006) in a model with monopolistic firms and real rigidities. Second, when sectors have different market powers, the heterogeneity in market power may amplify or attenuate the real effects of monetary shocks depending on the correlation between market power $\varphi_j$ and price stickiness $\lambda_j$. Intuitively, when market power is positively correlated with price stickiness, sticky sectors not only make slower price adjustments (due to a high $\lambda_j$) but also smaller price adjustments (due to a high $\varphi_j$) than flexible sectors.

Expression (20) provides a decomposition of the cumulative output response. The term $E_j \left[\frac{\lambda_j}{1-\lambda_j}\right]$ gives the cumulative output response in a standard heterogeneous sector monopolistically competitive Calvo model. The multiplier $E_j\left[\frac{\Lambda_j(1-\lambda_j)}{\lambda_j(1-\Lambda_j)}\right]$ summarizes the amplification effect of firms' market power on the aggregate output response. Lastly, $Cov_j\left[\frac{\lambda_j}{1-\lambda_j}, \frac{\Lambda_j(1-\lambda_j)}{\lambda_j(1-\Lambda_j)}\right]$ is a term analogous to the covariance term in (19), highlighting the importance of the correlation between firms' market power and price stickiness across sectors. We note that Wang and Werning (2022) derived an expression similar to (20) in their continuous-time model. A contribution of our paper is to empirically quantify the relative importance of these channels.

## 5.1 Role of market power in homogeneous sector models

To unpack the mechanisms influencing inflation dynamics, we discuss aggregate dynamics in different versions of the model, where we separately shut down the effects of strategic complementarity and sector heterogeneity in price stickiness and strategic complementarity. To facilitate this exercise, it is useful to first consider impacts in a homogenous sector version of the model, which yields the following corrollary.

**Corollary 1** *With symmetric firms and homogeneous sectors (i.e., $\varphi_{ij} = \varphi$, $\lambda_j = \lambda$), the NKPC is given by*

$$\widehat{\pi}_t = \frac{(1-\beta\lambda)(1-\lambda)}{(1+\varphi)\,\lambda}\widehat{mc}_t + \beta\mathbb{E}_t\widehat{\pi}_{t+1}, \tag{21}$$

*where $\widehat{mc}_t$ is the real marginal cost. With market power ($\varphi \neq 0$), the slope of NKPC is reduced by a factor of $1/(1+\varphi)$. In response to a permanent monetary shock, the sector price, inflation and output dynamics are given by*

$$\widehat{P}_\tau = 1 - \Lambda^{\tau+1}, \quad \widehat{\pi}_\tau = (1-\Lambda)\Lambda^\tau \quad \textit{and} \quad \widehat{c}_\tau = \Lambda^{\tau+1} \quad \forall \tau \geq 0, \tag{22}$$

*where*

$$\Lambda \equiv \frac{1}{2}\left[\frac{1+\lambda\varphi+\beta\lambda(\lambda+\varphi)}{\beta\lambda(1+\varphi)} - \sqrt{\left(\frac{1+\lambda\varphi+\beta\lambda(\lambda+\varphi)}{\beta\lambda(1+\varphi)}\right)^2 - \frac{4}{\beta}}\right]. \tag{23}$$

*With market power ($\varphi \neq 0$), the cumulative output response is amplified by $\frac{\Lambda(1-\lambda)}{\lambda(1-\Lambda)}$ relative to an alternative model with the same level of price stickiness but no market power.*

***Proof.*** *See Appendix B.3.*

Under oligopolistic competition, the slope of the NKPC in the homogeneous sector model is reduced by a factor of $\frac{1}{1+\varphi}$ relative to the slope under monopolistic competition. At the level of strategic complementarity implied by the idiosyncratic cost pass-through estimated in Section 4, $\varphi^{Data} = 0.43$, the slope of NKPC is reduced by 30%, implying a 28% larger cumulative output response. This effect of strategic complementarity is substantial. For example, if markups were to increase by 10 percentage points over the next decade—the decennial rate of increase in market power over the last four decades documented in De Loecker, Eeckhout and Unger (2020)—the NKPC would flatten by an additional 12%.[16] Our empirical evidence supports conclusions in Mongey (2021) and Wang and Werning (2022) that models with a reasonable degree of oligopolistic competition provide significant amplification of the effects of nominal rigidities in standard New Keynesian models.

### 5.2 Role of sector heterogeneity

How does sector heterogeneity affect this amplification effect? In this subsection, we quantify the importance of the channels highlighted in Proposition 3 using a multi-sector oligopolistic competition model that is calibrated to match the sector price stickiness $\lambda_j$ and market power $\varphi_j$ estimated in Section 4.2.[17] To dissect the underlying channels, we compare the aggregate dynamics in our benchmark model with three counterfactual alternative models that shut down one of the channels at a time.

Panel (a) of Figure 6 compares output impulse responses to an unanticipated 1% permanent monetary shock in four different models. The gray line shows the baseline output response to a monetary shock in the standard one-sector monopolistic competition Calvo model, where aggregate dynamics are given by (22) with $\Lambda = \lambda = 0.42$ calibrated to match the average price stickiness in the data. The black line shows the response from an alternative monopolistic competition Calvo model with sector heterogeneity in price stickiness, calibrated to match the average price stickiness in each 4-digit NAICS industry. Both models have the same aggregate price stickiness, and the difference

[16] Our estimated $\varphi^{Data} = 0.43$ and mean log markup $\ln(\mu^{Data}) = 0.34$ suggest an elasticity of substitution $\theta = 4.8$. A 10 percentage point increase in the markup level implies $\ln(\mu^{new}) = 0.41$. Assuming the same elasticity of substitution, this implies $\varphi^{new} = 0.73$ and thus $1/(1 + \varphi^{new}) = 0.58$.

[17] Specifically, we calibrate the sector market power using the estimated pass-through to idiosyncratic cost shocks in each sector, i.e., $\varphi_j^{Est} = 1 - 1/\psi_j^{Est}$ and use Propositions 2 and 3 to calculate $\Lambda_j$ and the aggregate dynamics.

in output responses reflects the role of sector heterogeneity in price stickiness, as discussed by Carvalho (2006). The red line shows the output response allowing for homogeneous market power (with $\varphi = 0.43$) and heterogeneous price stickiness. Finally, the blue line shows the response in our benchmark model calibrated to match the heterogeneity in both $\varphi_j$ and $\lambda_j$ found in the data.

(a) Output response to MP shock: $\widehat{c}_\tau$ (b) Heterogeneity effect: $\Upsilon_\tau \Lambda^{\tau+1}$

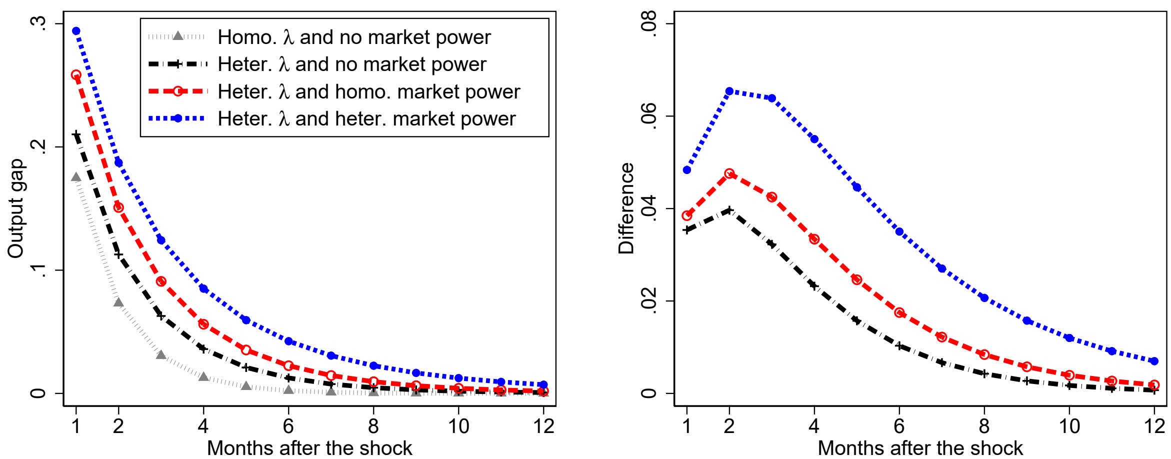


Figure 6: Amplification of monetary non-neutrality due to sector heterogeneity

Notes: The figure provides responses to an unanticipated permanent 1% increase in the money supply. Panel (a) reports output impulse responses. Panel (b) reports the difference between the aggregate output response and the response in an alternative homogeneous sector model with the same aggregate $\Lambda$. Models are based on weighted estimates from NAICS4 industries.

The difference in output responses combines the effects of strategic pricing complementarity and heterogeneity in market power and price stickiness. To distinguish the heterogeneity effect, we rewrite the output response into two terms using the relationships (18) and (19) in Proposition 3:

$$\widehat{c}_\tau = 1 - \widehat{P}_\tau = \Lambda^{\tau+1} + \underbrace{\Upsilon_\tau \Lambda^{\tau+1}}_{\text{heterogeneity effect} \geq 0}, \tag{24}$$

where $\Lambda \equiv \sum_j \alpha_j \Lambda_j$, and $\Upsilon_\tau \equiv \sum_j \alpha_j \Lambda_j^{\tau+1} / \Lambda^{\tau+1} - 1 \geq 0$ represents the additional output amplification due to sector heterogeneity (in price stickiness, market power, or both).[18] For comparison, we calibrate an alternative homogeneous sector model with the same $\Lambda$ so that the difference in output responses in the two models can be attributed to sector heterogeneity.

[18]Note that $\Upsilon_\tau \geq 0$ by Jensen's inequality.

Panel (b) of Figure 6 shows the additional output response due to sector heterogeneity. Comparing the red and black lines, we see that allowing for homogeneous market power leads to a small additional amplification of the output response through sector heterogeneity in price stickiness. Comparison of the blue and red lines shows that heterogeneity in market power significantly amplifies the output response. This amplification is driven by the positive correlation between price stickiness and market power observed in the wholesale price data.[19] In a counterfactual model in which the market power is heterogeneous but randomly assigned (i.e., it is uncorrelated with price stickiness), the output response is similar to the red line with homogeneous market power.

**Summary.** Table 3 summarizes the key quantitative takeaways for the models we discussed in this section. For each version of the model, Table 3 reports three statistics: (1) the cumulative output response to an unanticipated permanent 1% increase in money supply, (2) the price stickiness multiplier required to match the output response, and (3) the implied slope of the NKPC. Column (1) provides the statistics for the baseline model—the standard one-sector Calvo model with monopopolistic competition ("MC(1)"). The statistics for other versions of the model are expressed as ratios to the corresponding baseline statistics. Panels (a) and (b) of Table 3 report statistics based on NAICS4 and NAPCS7 estimates, respectively (we will focus on Panel (a)).

Relative to the MC(1) baseline, the output response is amplified by 1.24 in the model with heterogeneity in price stickiness (column 3), by 1.57 when there is homogeneous strategic complementarity and heterogeneity in price stickiness (column 4), and by 1.96 when both strategic complementarity and price stickiness vary across sectors (column 5). We can approximate these effects using a standard one-sector Calvo model in which nominal price stickiness $\lambda$ is increased by a factor of 1.13, 1.27, and 1.40, respectively.[20]

In sum, our empirical estimates imply a substantial degree of strategic pricing complementarity

[19] More precisely, the amplification or attenuation effect depends on the correlation between the relevant market power component in $\Lambda_j$, i.e., $\varphi_j/(1+\varphi_j)$, and the price stickiness $\lambda_j$ across sectors. In the wholesale price data, this correlation is positive at about 0.3 (Figure B3).

[20] At the aggregate level, a calibrated one-sector Calvo model with Kimball demand can match both the average price stickiness and the *total* real impact of a monetary shock in the models in Table 3. For example, assuming $\theta = 4.8$ (as in our benchmark model), the cumulative output response in the homogeneous sector oligopolistic competition model in column 2 of Table 3 can be matched in the one-sector Calvo model with Kimball demand by setting the Kimball demand superelasticity to 1.63, while matching the cumulative output response in our benchmark model in column 5 requires a superelasticity of 6.76. See Appendix B.8 for more details.

Table 3: Statistics in a multi-sector oligopoly model with sticky prices

| Statistic | Baseline | × Relative to Baseline | | | |
|---|---|---|---|---|---|
| | MC(1) $(\lambda, \varphi = 0)$ | OC(1) $(\lambda, \varphi)$ | MC($J$) $(\lambda_j, \varphi = 0)$ | OC($J$) $(\lambda_j, \varphi)$ | OC($J$) $(\lambda_j, \varphi_j)$ |
| | (1) | (2) | (3) | (4) | (5) |
| *(a) NAICS4 sectors* | | | | | |
| Output Response | 0.72 | 1.28 | 1.24 | 1.57 | 1.96 |
| Price Stickiness | 0.42 | 1.15 | 1.13 | 1.27 | 1.40 |
| Slope of NKPC | 0.81 | 0.70 | 0.73 | 0.52 | 0.36 |
| *(b) NAPCS7 products* | | | | | |
| Output Response | 0.82 | 1.27 | 1.47 | 1.84 | 2.38 |
| Price Stickiness | 0.45 | 1.13 | 1.21 | 1.33 | 1.47 |
| Slope of NKPC | 0.67 | 0.70 | 0.56 | 0.40 | 0.26 |

Notes: The table provides model statistics based on weighted estimates from NAICS4 industries (Panel a) and NAPCS7 products (Panel b). The first row of each panel reports the cumulative response of aggregate output (in %) to an unanticipated permanent 1% increase in the money supply. The second row of each panel reports price stickiness $\lambda$ in a standard monopolistically competitive model in column (1) that implies the output response in the alternative version of the model. The third row of each panel reports the implied slope of NKPC. Column (1) gives the statistics for the standard one-sector Calvo model with monopolistic competition ("MC(1)"), where price stickiness is equal to the weighted mean price stickiness in the data. Statistics for models in columns (2)–(5) are expressed relative to statistics for MC(1). Column (2) reports the results for an oligopolistically competitive model with homogeneous sectors ("OC(1)"), where $\lambda$ is set to the weighted mean price stickiness in the data and $\varphi = 0.43$. Column (3) reports statistics for an MC model with heterogeneous sectors ("MC(J)"), where the price stickiness in each sector is calibrated to match the data. Column (4) reports statistics for an OC model with heterogeneity in price stickiness and homogeneous market power, where $\varphi = 0.43$. Column (5) reports statistics for an OC model with heterogeneity in both price stickiness and market power, calibrated to match the estimates in Section 4.2.

in oligopolistic markets. The slope of NKPC in the multi-sector model that matches the heterogeneity in price stickiness and strategic complementarity observed in the data is only one-third of the slope in the standard one-sector model without real rigidities. Of the 64% difference in slope (column 5), 30 percentage points are due to the average effect of oligopolistic competition without sector heterogeneity (column 2), an additional 18 percentage points are due to heterogeneity in price stickiness (column 4), and the remaining 16 percentage points capture the positive correlation of price stickiness and market power across sectors.

## 6 Conclusions

Using unique data from Canadian wholesalers, we present evidence that firm-product price adjustments depend on the degree of market power and price stickiness within and across sectors. The estimated pass-through of idiosyncratic and common cost components to wholesale prices are in line with predictions of a model with oligopolistic distributors and sticky prices. Through the lens of our model, our estimates suggest that strategic pricing complementarity in the wholesale industry is substantial, e.g., reducing the slope of the NKPC by 30% in a one-sector model and by 64% in a multi-sector model.

The main takeaway is that, in oligopolistic markets, inflation dynamics and transmission of monetary policy or exchange rate shocks depend on the joint distribution of market power and price stickiness in the economy. Future research could explore how this joint distribution evolves over time. For example, if markups were to rise faster in more concentrated sectors, the NKPC would flatten more than if markups were to grow equally across sectors, because more concentrated sectors tend to have stickier prices. Future work should also study how market power influences the transmission of monetary policy in the wake of large inflation swings, such as those observed in the aftermath of the 2020–2022 COVID-19 pandemic. To account for the variation in price flexibility during such events (Montag and Villar, 2023; Cavallo and Kryvtsov, 2024), one needs to incorporate *endogenous* price flexibility in oligopolistic models with sector heterogeneity. Finally, future analyses could focus on how other sources of strategic pricing complementarities—due to non-CES preferences (Kimball, 1995), intermediate inputs (Basu, 1995), firm-specific production factors (Altig, Christiano, Eichenbaum and Lindé, 2011), or "real flexibilities" (Dotsey and King, 2006)—influence inflation dynamics in oligopolistic environments.

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