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

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Abstract

We study how the interaction of market power and nominal price rigidity influences 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 Using unpublished micro data for Canadian wholesale firms, we estimate that idiosyncratic cost pass-through is incomplete at 70% and independent of the degree of sector price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. A higher degree of sector or firm market power lowers the pass-through of both types of cost shocks. These estimates imply a degree of strategic complementarity that lowers the slope of the New Keynesian Phillips Curve by 30% in one-sector model and by 74% in 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 shocks. 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) 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 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 by 30% in one-sector model and by 74% in multi-sector model.

While our model builds on recent literature of aggregated models with oligopolistic markets,[1] we make additional assumptions that capture the key features of pricing behaviour of wholesale firms which enable 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., supplier's price) are sticky as in Calvo (1983), and their adjustments are perfectly synchronized, which we show is largely the case in the data. We derive a closed-form condition for adjustment in the distributor reset 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 for adjusting 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 Classifica-

[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).

tion System (NAICS4) or 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 for 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 the 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. 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 wholesaler's adjusted selling prices. Our empirical specification offers several advantages for estimating the joint contribution of price stickiness and market power to firm-product price adjustments: (i) it accounts for the effect of price stickiness on the degree of pass-through at monthly frequency; (ii) it incorporates the observed margin as a reliable measure of market power; (iii) it demarcates pass-through of idiosyncratic versus common cost shocks; and (iv) it distinguishes price stickiness and market power for different levels of aggregation.

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 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 mostly driven by sector-level price stickiness rather than by firm or product stickiness. Finally, a higher degree of sector or firm market power lowers the pass-through of both types of cost shocks.

These findings have important implications for inflation dynamics. Under oligopolistic competition, the slope of the New Keynesian Phillips Curve (NKPC) in 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 NKPC in the multi-sector model that matches heterogeneity in price stickiness and strategic complementarity is only *one-fourth* of the slope in the standard one-sector model without real ridigities. The additional amplification in multi-sector model is due to 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 of nominal price rigidity and strategic complementarity across sectors that we observe in the data. Overall, our empirical estimates imply that the joint variation of price stickiness and market power across sectors more than double propagation of nominal shocks obtained in models with identical sectors.

The contributions of this paper lie at an 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. While 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 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. Second, 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) find that goods with higher frequency of price adjustments in the U.S. import price micro data tend to have higher long-run exchange rate pass-through. They argue that 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 missing 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 distributors' cost changes into idiosyncratic and common components, lays out our estimation method, and reports estimation

[2] Our paper also connects to a broader macro literature that emphasizes the role of 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.

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 which depend on changes in own supply costs and costs of competitors. The pass-through of own cost change is incomplete due to strategic pricing complementarity arising endogenously under oligopolistic competition. The pass-through of the common component of sector supply cost 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 lay out key assumptions and features of the model. We relegate 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 disutility from working, 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 β hold cash M_t, government bonds B_t returning risk-free rate R_t, pay lump-sum taxes T_t, and obtain dividends Π_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

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

and the sequence of cash-in-advance constraints for consumption spending

$$\sum_{j=1}^{J} P_{jt} c_{jt} \leq M_t.$$

Optimal consumption shares are constant:

$$\frac{P_{jt} c_{jt}}{P_t c_t} = \alpha_j. \tag{1}$$

where P_t denotes the price of the bundle c_t.

Assuming the interest rate never binds at zero, the cash-in-advance constraint is always binding, and 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 labor supply satisfies

$$W_t = P_t c_t = M_t. \tag{2}$$

The production sector consists of global 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 Cobb-Douglas consumption aggregator lead to conditions (1), (2) and allow us to analyze price dynamics in a sector independently from prices in other sectors.

Sector output and prices. The output in each sector, c_{jt}, is aggregated over goods supplied by a limited number of distributors using a CES technology:

$$c_{jt} = \left[\sum_{i=1}^{N_j} (c_{ijt})^{\frac{\theta-1}{\theta}} \right]^{\frac{\theta}{(\theta-1)}}, \tag{3}$$

where N_j is the number of distributors in sector j, θ is the within-sector elasticity of substitution,

c_{ijt} is the demand for distributor i's output from the consumer's optimization problem:

$$c_{ijt} = \alpha_j \left(\frac{P_{ijt}}{P_{jt}}\right)^{-\theta} \frac{P_t}{P_{jt}} c_t, \tag{4}$$

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 is taken as given. The distributor uses linear technology to produce c_{ijt} units of good:

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

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

Distributor's 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). Similar to Mongey (2021), we assume that in period t an adjusting firm observes marginal cost realizations for all firms, but it does not observe Calvo adjustment signals 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. 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.

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

$$P_{ijt,t} = \frac{\mathbb{E}_t \sum_{\tau=0}^{\infty} (\beta\lambda)^{\tau}\, \vartheta_{ijt+\tau,t} c_{ijt+\tau,t}}{\mathbb{E}_t \sum_{\tau=0}^{\infty} (\beta\lambda)^{\tau}\, (\vartheta_{ijt+\tau,t} - 1) c_{ijt+\tau,t}/Q_{ijt+\tau}}, \tag{5}$$

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 $t+\tau$ under Cournot competition:[3]

$$\mathbb{E}_t \vartheta_{ijt+\tau,t} = \mathbb{E}_t \left[\frac{1}{\theta}(1 - s_{ijt+\tau,t}) + s_{ijt+\tau,t} \right]^{-1} \tag{6}$$

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

$$\mathbb{E}_t s_{ijt+\tau,t} \equiv \mathbb{E}_t \left[\frac{P_{ijt+\tau} c_{ijt+\tau}}{P_{jt+\tau} c_{jt+\tau}} \right] = \mathbb{E}_t \left[\frac{(P_{ijt+\tau})^{1-\theta}}{\sum_{i=1}^{N_j} (P_{ijt+\tau})^{1-\theta}} \right]. \tag{7}$$

We emphasize that (6) and (7) hold in expectations because the actual realizations of effective demand elasticity and market share are influenced by the realizations of the Calvo signal in the finite population of distributors. As we explain below, the optimal reset price depends only on expected values of current and future variables in (5), and therefore, variation in the realized fraction of adjusting prices has no effect on adjusting prices.

Producers. Varieties are supplied to distributors by producers competing in monopolistically competitive global 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 $Q_{ijt} = Q_{ijt}^*$, 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 for distributor's price changes

There are three challenges to solving (5) 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. Third, ex-post realizations of the Calvo signal across competitors introduce variations in the fraction of adjusters and influence realized sector and aggregate prices.

Strategic pricing complementarity. Under log-linear approximation of (6) and (7), the deviation of the firm's expected markup $\mathbb{E}_t \mu_{ijt} \equiv \mathbb{E}_t \frac{\vartheta_{ijt+\tau,t}}{\vartheta_{ijt+\tau,t}-1}$ from the steady state decreases with

[3] Under Bertrand competition $\vartheta_{ijt+\tau,t} = \mathbb{E}_t \left[\theta(1 - s_{ijt+\tau,t}) + s_{ijt+\tau,t}\right]$. Appendix B also provides the results under Bertrand competition.

the deviation of the firm's price from the expected sector price:

$$\mathbb{E}_t\widehat{\mu}_{ijt+\tau,t} = \kappa_{ij}\mathbb{E}_t\widehat{s}_{ijt+\tau,t} = -\kappa_{ij}(\theta-1)\left[\widehat{P}_{ijt,t} - \mathbb{E}_t\widehat{P}_{jt+\tau}\right], \tag{8}$$

where hatted variables represent log-linear deviations of corresponding variables from steady state, and $\kappa_{ij} = \frac{s_{ij}}{1-s_{ij}}$ is the (steady-state) markup elasticity with respect to changes in the expected market share under Cournot competition.

Equation (8) shows that firms have an incentive to keep their markup low as their price is pushed above the sector average price, known as strategic pricing complementarity.[4] It arises endogenously in oligopolistic markets, and its strength is governed by φ_{ij}:

$$\varphi_{ij} \equiv \kappa_{ij}(\theta-1) = \frac{s_{ij}}{1-s_{ij}}(\theta-1). \tag{9}$$

Pricing complementarity is stronger with market power, i.e., φ_{ij} is increasing in firm i's market share, s_{ijt}. As demonstrated in Wang and Werning (2022), φ_{ij} plays a key role in the analysis of micro and macro price dynamics under oligopolistic competition. As we show in Section 4, one can estimate φ_{ij} from the responses of the distributors' prices to idiosyncratic and common cost shocks.

Plugging (8) in the log-linearized pricing equation (5) and rearranging yields the reset price as the sum of its expected costs and expected sector prices:

$$\widehat{P}_{ijt,t} = \frac{1-\beta\lambda}{1+\varphi_{ij}}\sum_{\tau=0}^{\infty}(\beta\lambda)^{\tau}[\mathbb{E}_t\widehat{Q}_{ijt+\tau,t} + \varphi_{ij}\mathbb{E}_t\widehat{P}_{jt+\tau}]. \tag{10}$$

Expected sector prices. The 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 (10) becomes

$$\mathbb{E}_t\widehat{P}_{jt,t} = \sum_i\left\{s_{ij}\frac{(1-\beta\lambda)}{(1+\varphi_{ij})}\sum_{\tau=0}^{\infty}(\beta\lambda)^{\tau}[\mathbb{E}_t\widehat{Q}_{ijt+\tau,t} + \varphi_{ij}\mathbb{E}_t\widehat{P}_{jt+\tau}]\right\}. \tag{11}$$

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

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

$$\mathbb{E}_t \widehat{P}_{jt+\tau} = \mathbb{E}_t \sum_i s_{ijt+\tau} \widehat{P}_{ijt+\tau} \tag{12}$$

$$= (1-\lambda)\mathbb{E}_t \sum_i s_{ijt+\tau} \widehat{P}_{ijt+\tau,t+\tau} + \lambda \mathbb{E}_t \sum_i s_{ijt+\tau} \widehat{P}_{ijt+\tau-1} \tag{13}$$

$$\approx (1-\lambda)\mathbb{E}_t \widehat{P}_{jt+\tau,t+\tau} + \lambda \mathbb{E}_t \widehat{P}_{jt+\tau-1}, \tag{14}$$

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 sector price P_{jt} are at most second order.[5]

Combining (11) and (14) gives the equation for expected sector inflation $\mathbb{E}_t \widehat{\pi}_{jt} \equiv \mathbb{E}_t(\widehat{P}_{jt} - \widehat{P}_{jt-1})$:

$$\mathbb{E}_t \widehat{\pi}_{jt} = \sum_i s_{ij} \frac{(1-\beta\lambda)(1-\lambda)}{\lambda\,(1+\varphi_{ij})} \mathbb{E}_t(\widehat{Q}_{ijt,t} - \widehat{P}_{jt}) + \beta \mathbb{E}_t \widehat{\pi}_{jt+1}. \tag{15}$$

Given expected cost processes $\{\mathbb{E}_t \widehat{Q}_{ijt+\tau,t}\}_{\tau=0}^{\infty}$, equation (15) fully characterizes the dynamics of expected sector prices $\{\mathbb{E}_t \widehat{P}_{jt+\tau}\}_{\tau=0}^{\infty}$. Note that (15) is the sectoral New Keynesian Phillips Curve (in expectations). We use this NKPC relationship in Section 5, where we discuss implications of the estimated degree of strategic interaction and market power for sector and aggregate price dynamics.

Granular variation in price adjustments. Although the probability of price changes is constant due to Calvo pricing, the realized fraction of adjusting prices varies over time due to a finite number of firms realizing the Calvo signal from the Poisson process. Variation in the fraction of adjusting prices creates additional "granular" fluctuations in sector and aggregate prices.

Given the timing assumptions, the firm's reset price in (10) depends on expected values of current and future sector prices. As we show in Appendix B.1, these expected values do not depend on variations in realized fraction of price changes and are always the same for all firms.

Regarding aggregate price, we follow Wang and Werning (2022) and assume that the number of

[5]Intuitively, because market shares add up to 1, 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 δ that changes firm i's market share by $ds_i(\delta)$ and price by $dP_i(\delta)$, and that prices are the same in steady state, $P_i = P$. The first-order effect of δ on the weighted sum of prices is $P\sum_i ds_i(\delta) + \sum_i s_i dP(\delta)$. Since market shares must add to 1, $\sum_i ds_i(\delta) = 0$ and variation in market share has at most a second-order effect on the weighted mean.

similar sectors is sufficiently large so that the variation in the sectoral fraction of adjusting prices does not have a first-order effect on the aggregate price.[6]

Price synchronization. Our last assumption is that distributors and producers of the same variety i face identical Poisson process for price adjustments, i.e., distributor i's price P_{ijt} changes if and only if producer i's price Q_{ijt} changes. This assumption is born out in the data: in Section 3 we provide evidence that wholesale prices are indeed highly synchronized with producer prices. Under this assumption, the distributor's cost at any period over price duration is equal to the cost at the last reset, i.e.,

$$\mathbb{E}_t Q_{ijt+\tau,t} = Q_{ijt,t} = Q^*_{ijt} \tag{16}$$

for all $\tau = 0, 1, ...$ as long as the price remains unchanged. This assumption is convenient for two reasons. First, we do not need to specify the specific process for producer's marginal cost,[7] because the reset price in period t depends only on the current realizations of all supply costs $Q_{ijt,t}, \forall i$, which the firm observes when adjusting its price. Second, our model with oligopolistic distributors alongside monopolistically competitive producers yields the same aggregate dynamics as a model with oligopolistically competitive producers and no distributors (see Appendix B.3). This facilitates direct comparisons of our theoretical results with those obtained from oligopolistic models without distributors (e.g., Wang and Werning 2022).

The following proposition provides the closed form expression for the distributor's price change.

Proposition 1 *Under perfect price synchronization, the optimal reset price response to idiosyncratic and common cost shocks, up to a first order approximation, is*

$$\widehat{P}_{ijt,t} = \frac{1}{1+\varphi_{ij}}\left(\widehat{Q}^*_{ijt} - \widehat{Q}^*_{jt}\right) + \left[\frac{1}{1+\varphi_{ij}} + \frac{\varphi_{ij}}{1+\varphi_{ij}}\left(\frac{1-\Lambda_j}{1-\beta\lambda\Lambda_j}\right)\varkappa_j\right]\widehat{Q}^*_{jt} \tag{17}$$

[6] Let $\alpha_z = \sum_{j\in z}\alpha_j$ denote the total market share of sectors with market structure z. Assuming a sufficiently large number of sectors in each structure type z, the aggregate price index can be expressed as:

$$\widehat{P}_t = \sum_z \alpha_z \widehat{P}_{zt} = (1-\lambda)\sum_z \alpha_z \widehat{P}_{zt,t} + \lambda \sum_z \alpha_z \widehat{P}_{zt-1} = (1-\lambda)\widehat{P}_{t,t} + \lambda \widehat{P}_{t-1},$$

where the law of large numbers is applied to derive the second equality. Consequently, the aggregate Phillips curve is essentially a sectoral share-weighted aggregation of the individual sectoral Phillips curves. In his model of many duopoly sectors and menu costs of price adjustments, Mongey (2021) provides a numerical solution for the entire distribution of individual price adjustments, within and across sectors.

[7] In Appendix B.1, we provide results for alternative assumptions about producer's marginal cost process.

where $\widehat{Q}^*_{jt} \equiv \sum_i s_{ij}\widehat{Q}^*_{ijt}$, *and*

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

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

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

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

Proof. *See Appendix B.1.*

Proposition 1 shows that distributor's reset price responds to its underlying idiosyncratic cost, $\widehat{Q}^*_{ijt} - \widehat{Q}^*_{jt}$, and the common sector cost $\widehat{Q}^*_{jt} \equiv \sum_i s_{ij}\widehat{Q}^*_{ijt}$. Figure 1 illustrates the key properties of the pass-through of these shocks to the distributor's reset price, using the case with symmetric firms.

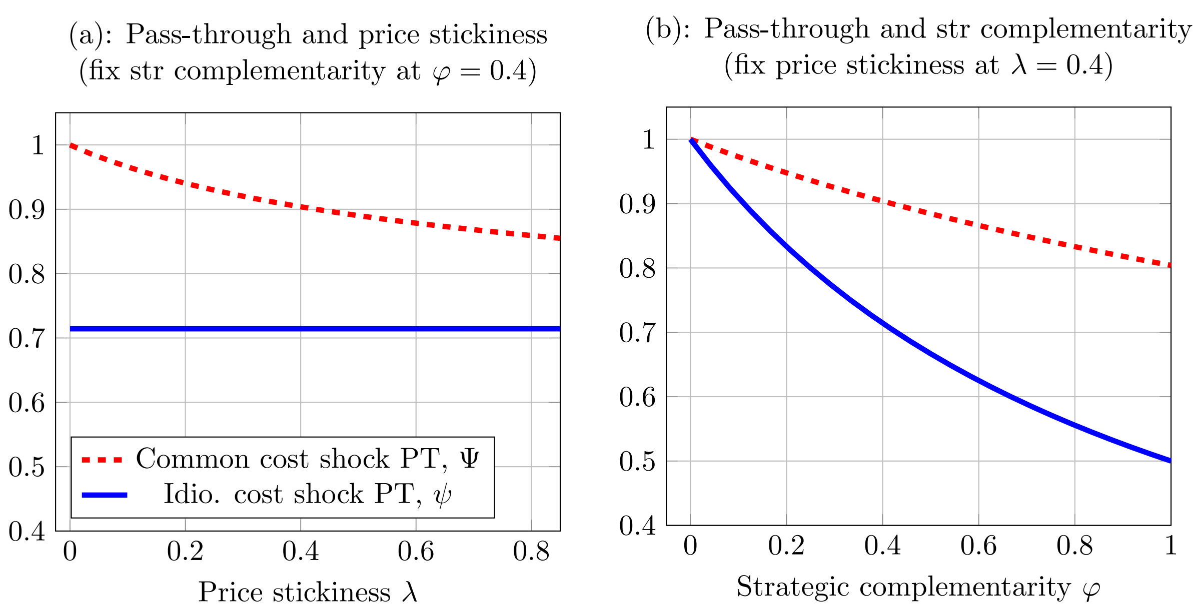


Figure 1: Idiosyncratic and common cost shock pass-through (symmetric firms)

The idiosyncratic cost pass-through (in sold blue), which we denote by $\psi_j \equiv \frac{1}{1+\varphi_j}$, decreases with the degree of strategic complementarity φ_j for this firm and sector, and it does not depend on the degree of price stickiness in the sector. The common cost pass-through (in dashed red), denoted by $\Psi_j \equiv \frac{1}{1+\varphi_j} + \frac{\varphi_j}{1+\varphi_j}\left(\frac{1-\Lambda_j}{1-\beta\lambda\Lambda_j}\right)\varkappa_j$, decreases with both strategic complementarity (albeit at a slower rate than ψ_j) and sector price stickiness.

Two special cases of Proposition 1 provide further intuition.

Special case 1: Flexible prices, $\lambda = 0$:

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

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]. Similar 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 sector. Even in asymmetric cases, the common shock pass-through is close to one when cost shocks are small.[8] By contrast, a firm only partially responds to idiosyncratic cost shock in an effort to prevent its price from deviating too far from competitors' prices, which would stretch its market share to be too high or too low. Such strategic motives are absent when all competing firms are hit by the common shock, resulting in its complete pass-through.

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, shown in Figure 1(a). By contrast, the firm's own cost directly hits only own price, and its pass-through is not directly influenced by the composition of adjusters and non-adjusters. Hence, idiosyncratic cost pass-

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

through does not depend on the degree of price stickiness.[9]

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 shock ($\psi_{ij} \to 1$, $\Psi_{ij} \to 1$) by adjusting the price to changes in the 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 increasingly costly for the firm to accommodate its own cost shock than the cost that is common for the firm and its competitors. Therefore, as market power rises, idiosyncratic cost pass-through decreases faster than common cost pass-through.

3 Canadian Wholesale Trade price micro data

This paper uses unpublished survey-based price micro data from Statistics Canada's Services Producer Price Index program. The data we use is collected to construct the monthly WSPI published by Statistics Canada. 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 to 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 pre-determined list of reasons. Finally, the data also include information on currency in which prices are reported.

The survey program is longitudinal in design, with the goal of monitoring each product reported

[9] Amiti, Itskhoki and Konings (2019) demonstrate that under flexible prices, changes of competitors' prices are sufficient for inferring the firm's pass-through of common cost shocks. This is no longer the case under sticky prices because only adjusting competitors' prices are informative about their current costs. Our data provides direct cost measures for all wholesale firms, adjusting or not. Our model shows how changes in competitors' costs—in a sector where only some competitors change their prices—influence adjusting firm's reset price.

by a given establishment continuously over several collection cycles. Respondents are instructed to report up to six products that are representative of their wholesaling activity, chosen based on either contribution to annual sales or frequency of purchases.

The raw micro data used in the paper has not been cleaned prior to our receiving the data, and none of the prices in our data are imputed. To the extent that is possible, we exclude any remaining outliers and anomalies from the raw micro data, ensuring that all prices and price changes are as accurate as possible. 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 20 monthly observations, nearly all of which are consecutive. In terms of country of origin, the split across observations is 44% domestic, 32% U.S., 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.[10] 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, weighted statistics or regressions in the paper use the sampling revenue weight to capture the economic importance of firms in the population.

[10] 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 for 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 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 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 monthly fraction of selling price changes is defined as

$$Fr_j^P \equiv \frac{\sum_{i \in I_j} \sum_{t \in T_{ij}} \omega_{ij}^D \mathbb{1}\left[P_{ijt} \neq P_{ijt-1}\right]}{\sum_{i \in I_j} \sum_{t \in T_{ij}} \omega_{ij}^D} \tag{18}$$

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; ω_{ij}^D represents the "design weight" of the firm, calculated as the inverse of the probability of being selected; 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.

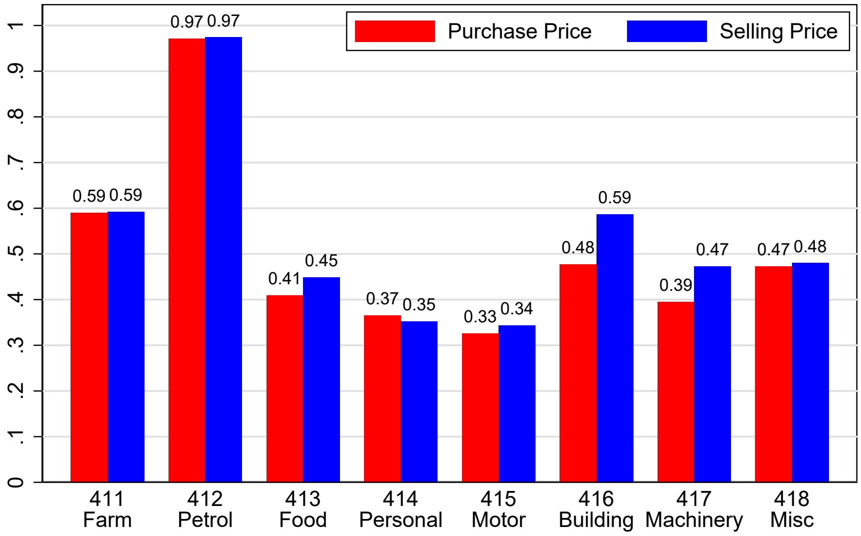


Figure 2: Average fraction of price changes, by 3-digit NAICS wholesale industry

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

(a) 4-digit NAICS industry level

(b) 7-digit NAPCS product level

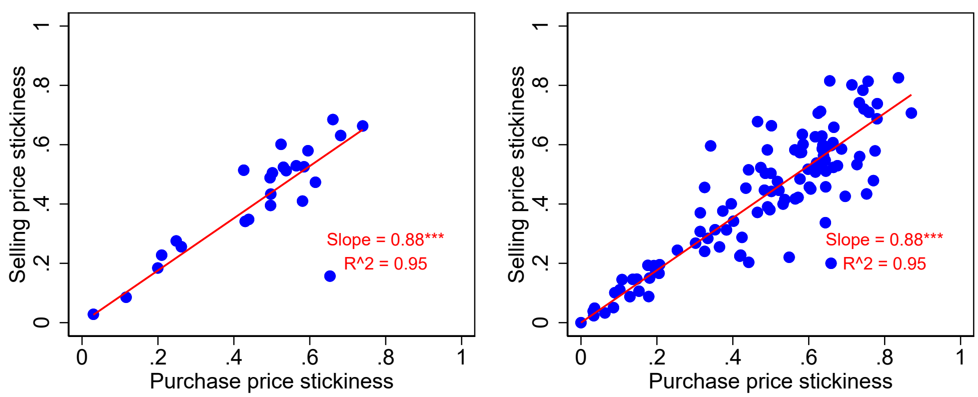


Figure 3: Selling and purchase price synchronization at the industry and product levels

Notes: Purchase (selling) price stickiness is given by λ_j^P (λ_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 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 time. And when the purchase price is unchanged from the previous month, the selling price is unchanged 75% of time. Derivation of the closed form in Section 2 relies on the assumption of perfect synchronization between purchase and selling price changes, which we show here is largely born out in the data.

Table 1: Synchronization at the firm-product level

		Selling price change	
		Yes	No
Purchase price change	Yes	0.8632	0.1368
	No	0.2503	0.7497

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 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. 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.[11]

In practice, a wholesaler may incur other costs, such as wage payments to its staff, 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

[11] 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 labor costs.[12] Other indirect costs such as the cost of maintaining distribution facilities should be less variable over short horizons and are therefore likely unrelated to marginal cost dynamics (see Appendix A.5). Second, measurement error would imply similar empirical estimates of idiosyncratic and common shock pass-through rates; our evidence strongly rejects their equality. Third, our empirical analysis uses firm-product fixed effects to control for the variation of unobserved cost components across firms and products. In all, we consider the firm-product margin as a reasonable markup proxy for the goals of this study.

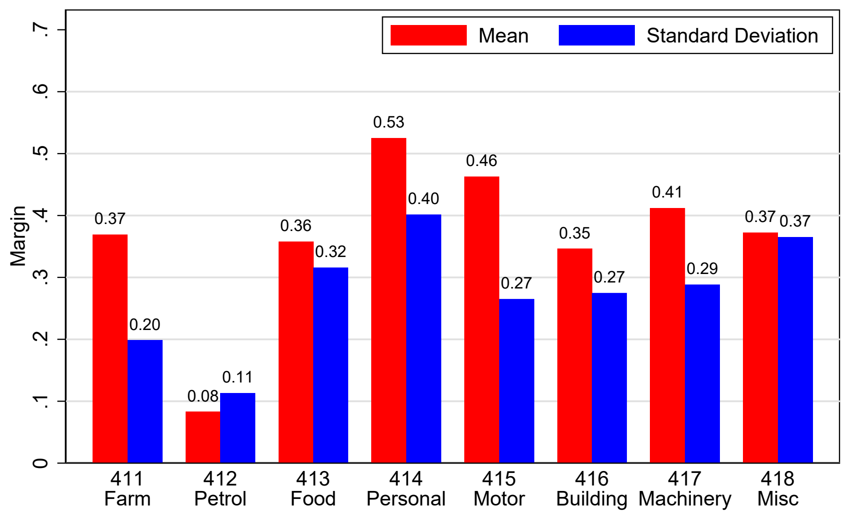


Figure 4: Average product margin, by 3-digit NAICS wholesale industry

Notes: Margin is the log of the ratio of 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 selling price change. We find strong support for our theoretical predictions: in oligopolistic markets,

[12]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.

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 an industry at the NAICS4 level. As a robustness check, we then repeat the analysis using an alternative 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 a closed-form relationship (17) 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 (17) in two steps. First, we decompose purchase price changes in a sector into the idiosyncratic and common components by using a 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

$$\Delta \ln(Q_{ijt}) = \epsilon_{jt} + \epsilon_{ijt}, \tag{19}$$

where ϵ_{jt} are the sector-month fixed effects and ϵ_{ijt} is the residual.[13] 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."

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

[13]Alternatively, the average cost change can be calculated as $\epsilon_{jt} = \left[\sum_{i \in I_{jt}} \Delta \ln(Q_{ijt})\right] / \left[\sum_{i \in I_{jt}} \mathbb{1}\right]$, where I_{jt} is the set of firm-products surveyed in sector j in month t.

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

$$\Delta \ln(P_{ijt}) = \underbrace{(\Psi_0 + \Psi_1\lambda_j + \Psi_2\lambda_{fj} + \Psi_3\lambda_{ij} + \Psi_4 D_j + \Psi_5 D_{ij})}_{\text{common cost pass-through}} \cdot \widehat{\epsilon}_{jt} + \underbrace{(\psi_0 + \psi_1\lambda_j + \psi_2\lambda_{fj} + \psi_3\lambda_{ij} + \psi_4 D_j + \psi_5 D_{ij})}_{\text{idiosyncratic cost pass-through}} \cdot \widehat{\epsilon}_{ijt} + FE_{ij} + \nu_{ijt}, \tag{20}$$

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

In specification (20), 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 market power measures. Price stickiness λ_j, λ_{fj}, λ_{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 margin to capture variation in market power.[14] 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. Appendix A.3 provides expressions for measures of price stickiness and market power. We estimate (20) with a panel fixed effects regression using all observations with non-zero selling price changes.

Specification (20) offers several advantages for 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 margins of heterogeneous distributors in concentrated markets. As a special case, specification (20) 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

[14] 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 φ_{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 θ: $\varphi_{ij} = \left(\frac{\theta-1}{\theta}\mu_{ij} - 1\right)(\theta - 1)$. 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 sale revenues because we do not observe the entire population of firms in each sector, and because margins in our dataset are observed at product level and monthly frequency.

data provides a direct measure of price markup which is a standard measure of market power. In particular, since in the data we observe distributors' cost directly, and these costs are plausibly exogenous to distributors' prices, we can estimate theoretical relationship (17) directly using specification (20). Studies relying on using observed competitors' prices for pass-through estimation face an additional challenge of addressing endogeneity of competitors' prices to underlying costs.[15]

Third, it distinguishes the pass-through of idiosyncratic and common cost shocks. Our model demonstrates how price stickiness and market power jointly and *defferentially* 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) and Wang and Werning (2022), and our model equation (17), demonstrate that the combined effects of nominal price rigidity and market power on micro price adjustments vary across firm-products within a sector as well as 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

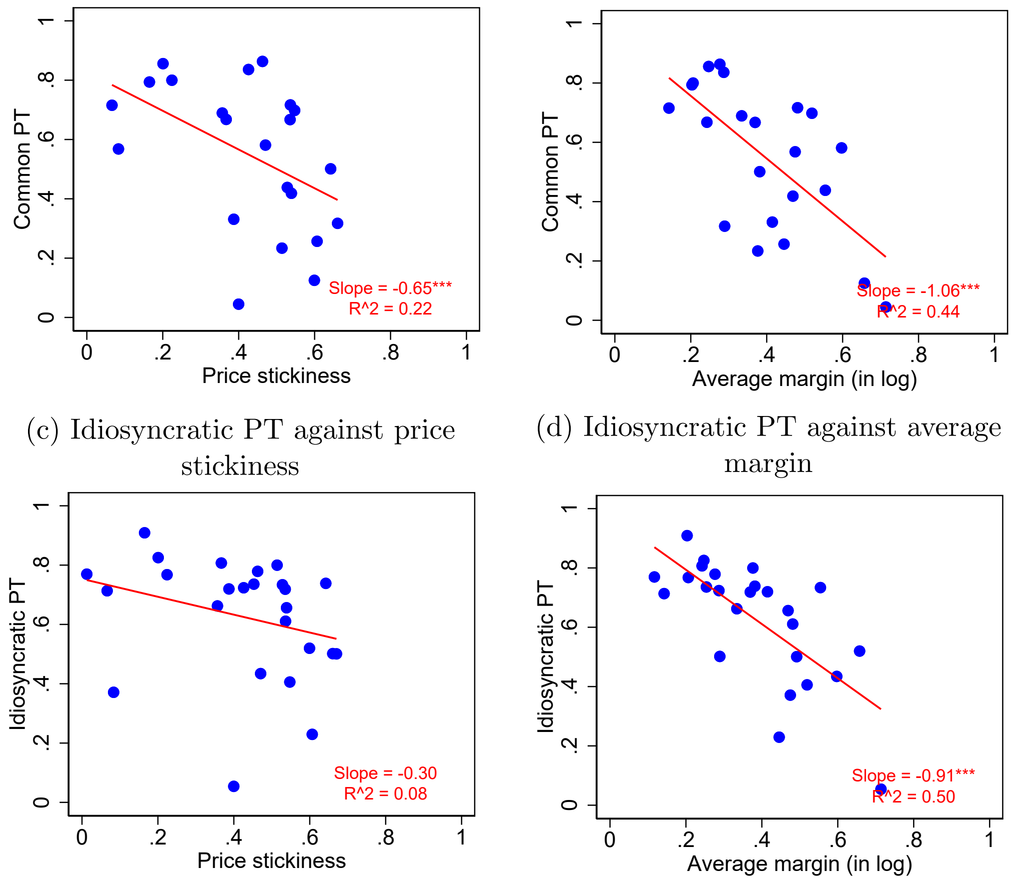
We first estimate (20) separately for each of the NAICS4 industries and NAPCS7 products. Figures 5 and 6 provide scatter plots of the estimated pass-through coefficients against the price stickiness and the average margin of the industry or product. The plots include the fitted line to summarize the 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 margin account for 53% (34%) of variance of the common cost pass-through across NAICS4 (NAPCS7) sectors, and for 82% (65%) of variance of the idiosyncratic

[15] 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.5.

cost pass-through.[16]

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.[17]



(a) Common PT against price stickiness

(b) Common PT against average margin

(c) Idiosyncratic PT against price stickiness

(d) Idiosyncratic PT against average margin

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

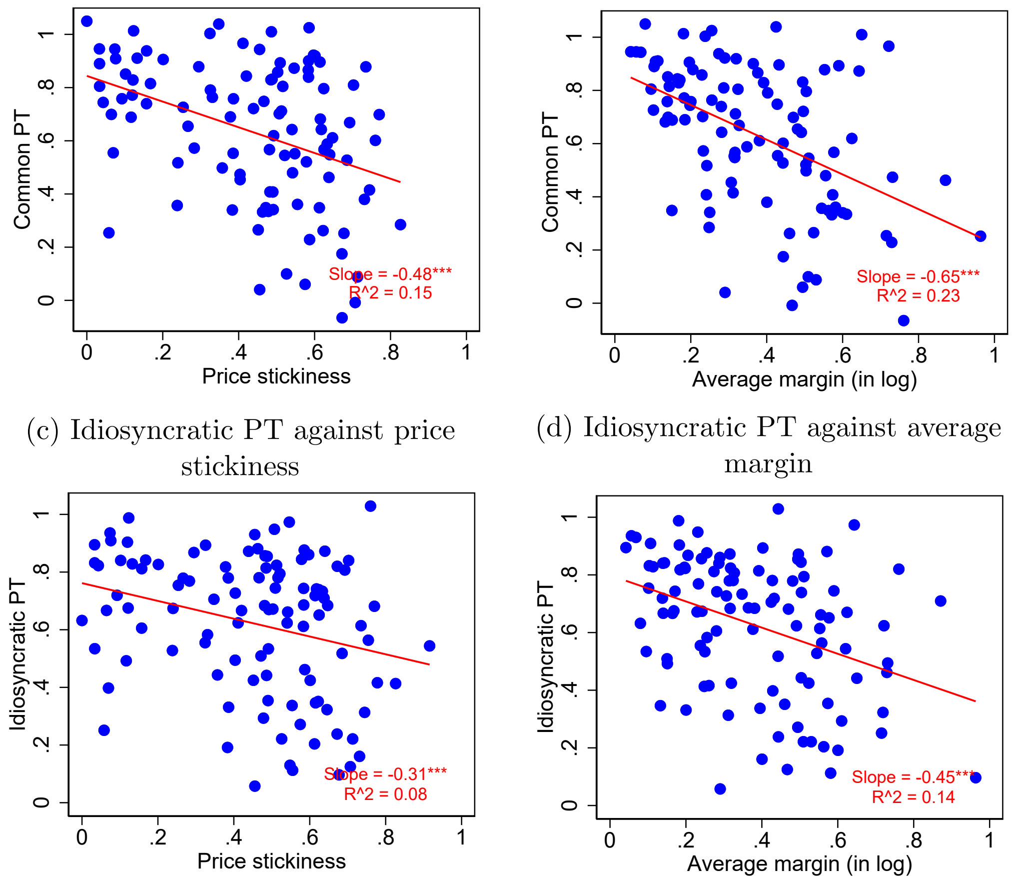
Note: The figures plot the estimated selling price pass-through to common and idiosyncratic cost shocks against the average price stickiness and markup measured at the NAICS4 industry level. Specifically, we estimate $\Delta \ln(P_{ijt}) = \Psi_j \epsilon_{jt}^{Est} + \psi_j \epsilon_{ijt}^{Est} + FE_{ij} + \nu_{ijt}$ 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 (Ψ_j^{Est}, ψ_j^{Est}) on the price stickiness λ_j or the average margin μ_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. While the pass-through significantly decreases with the average margin, the slope is not steeper than the

[16]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.3 provides detailed results.

[17]In our model, the degree of market power is synonymous with the degree of strategic complementarity.

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, only for NAICS4 sectors the slope is not statistically different from zero, and it is negative and significant for NAPCS7 sectors.



(a) Common PT against price stickiness

(b) Common PT against average margin

(c) Idiosyncratic PT against price stickiness

(d) Idiosyncratic PT against average margin

Figure 6: Estimates at the 7-digit NAPCS wholesale product 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 NAPCS7 product 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 product. For this graphical presentation, we have included only the products with estimated pass-through rates in the range of $[-0.1, 1.1]$ and an average margin $\mu_j < 1$. The red line in each figure represents the fitted line obtained by regressing the estimated coefficients (Ψ_j^{Est}, ψ_j^{Est}) on the price stickiness λ_j or the average margin μ_j. The slope and the R^2 of the fitted line are reported in the bottom right corner of each figure.

Because we estimate pass-through coefficients separately for each sector, these results do not incorporate variation of price stickiness and market power *across* sectors. In Appendix A.3 we document that sectors with high average margin tend to have stickier prices, with the slope of roughly 2/3: increasing sector's average log margin from 0.2 to 0.6 increases monthly price stickiness from 0.30 to 0.57, raising average price duration by roughly one month. To the extent higher price stickiness reflects higher market power (as opposed to higher prices stickiness given market power), the slope in panel (c) of Figures 5 and 6 would be flatter if we controlled for the negative effect of market power on the pass-through. Similarly, if higher sector margins are also accompanied by stickier prices, the slope in panel (d) of Figures 5 and 6 would be steeper if we controlled the muting effect of price stickiness on the pass-through. Hence, positive correlation of price stickiness and average sector margins can potentially explain both deviations of sector pass-through estimates from theory predictions in Figure 1.

4.3 Estimation results for all sectors

To incorporate cross-sector variation, we now estimate (20) for observations in all sectors (NAICS4 industries or NAPCS7 products). Tables 2 and 3 provide estimated pass-through coefficients capturing variation in price stickiness and market power both across and within sectors. We focus on NAICS estimates to summarize the main results.

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-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 × Sectoral stickiness		-1.16***	-1.02***	-1.00***	-0.96**	-0.70**
		(0.31)	(0.304)	(0.3)	(0.338)	(0.251)
Idio. cost × Sectoral 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-margin industry					-0.29**	-0.29**
					(0.106)	(0.095)
Idio. cost × High-margin industry					-0.25***	-0.24***
					(0.046)	(0.042)
Common cost × High-margin firm						-0.05
						(0.186)
Idio. cost × High-margin 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 margins. 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. Statistical significance, based on robust standard errors clustered at the firm level, is reported at the 1, 5 or 10 percent level which is indicated by ***, **, or * respectively.

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

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 firm-product level.[18] 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, consistent with 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 (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) and (3) confirm that this result is mostly driven by sector-level price stickiness rather than by firm or firm-product stickiness.

For a given degree of sector price stickiness, both common and idiosyncratic pass-through decrease with market power of the sector (columns 5 and 6 in Table 2), in line with 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.

[18] The negative interaction term between the idiosyncratic cost shock and the firm-product stickiness (column 4) suggests the pass-through of an idiosyncratic cost shock is decreasing in the price stickiness of the firm-product. In Appendix B.1, we show this empirical finding is consistent with a more general model that relaxes the assumption of perfect synchronization between cost and price adjustments.

The estimation results are generally similar when sectors are defined according to NAPCS7 product classification (Table 3). The differences in the magnitude and significance of some of the estimates likely reflect differences in 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 NAICS4 classification, the measure of sector price stickiness may be less accurate due to noise stemming from adjustments of individual firms or products.

Table 3: Pass-through estimates, 7-digit NAPCS wholesale products

	(1)	(2)	(3)	(4)	(5)	(6)
Common cost	0.79***	0.86***	0.86***	0.86***	0.89***	0.93***
	(0.038)	(0.063)	(0.063)	(0.063)	(0.044)	(0.032)
Idio. cost	0.69***	0.70***	0.70***	0.70***	0.75***	0.84***
	(0.028)	(0.065)	(0.065)	(0.065)	(0.042)	(0.037)
Common cost × Sectoral stickiness		-0.32*	-0.30*	-0.26	-0.23	-0.21
		(0.149)	(0.151)	(0.146)	(0.167)	(0.143)
Idio. cost × Sectoral stickiness		-0.02	0.06	0.04	0.04	0.01
		(0.137)	(0.14)	(0.142)	(0.102)	(0.092)
Common cost × Firm stickiness			-0.03			
			(0.134)			
Idio. cost × Firm stickiness			-0.23**			
			(0.074)			
Common cost × Firm-product stickiness				-0.14		
				(0.131)		
Idio. cost × Firm-product stickiness				-0.22**		
				(0.074)		
Common cost × High-margin industry					-0.22	-0.21
					(0.145)	(0.126)
Idio. cost × High-margin industry					-0.23**	-0.22*
					(0.085)	(0.087)
Common cost × High-margin firm						-0.18*
						(0.08)
Idio. cost × High-margin firm						-0.28***
						(0.034)
Observations	133,620	133,620	133,620	133,620	133,620	133,620
Firm-product fixed effects	✓	✓	✓	✓	✓	✓
R^2	0.54	0.54	0.54	0.54	0.55	0.57

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 margins. 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 product-time fixed effect, where product is defined as the firm-product's NAPCS7 product code. Idiosyncratic shocks are defined as the residual of this first-stage regression. Statistical significance, based on robust standard errors clustered at the firm level, is reported at the 1, 5 or 10 percent level which is indicated by ***, **, or * respectively.

5 Implications for inflation dynamics

To put the empirical estimates in perspective, we summarize inflation dynamics in the multi-sector model with oligopolistic competition using sector price stickiness λ_j and strategic complementarity φ_j estimated in Section 4.2. To unpack the mechanisms influencing inflation dynamics, we add statistics from simplified versions of the model, where we shut down the effects of sector heterogeneity in price stickiness, strategic complementarity, or market power.[19] For each version of the model, Table 4 reports three statistics: 1) the cumulative output response to an unanticipated permanent 1% increase in money supply, 2) price stickiness multiplier required to match the output response, and 3) the slope of the New Keynesian Phillips Curve (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 multiples of the baseline statistics. Panels (a) and (b) of Table 4 report statistics based on NAPCS7 and NAICS4 estimates, respectively (we will focus on Panel (a)).

Under oligopolistic competition ("OC(1)", column 2), the slope of the NKPC in 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 in Section 4, $\varphi^{Data} = 0.43$, the slope of NKPC is reduced by 30%. 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%.[20] Our empirical evidence supports conclusions in Mongey (2021) and Wang and Werning (2022) that models with reasonable degree of oligopolistic competition provide significant amplification of the effects of nominal rigidities in standard New Keynesian models.

The implications of strategic complementarities are stronger when we account for sector heterogeneity ("OC(J)", column 4). When we "turn on" heterogeneity in price stickiness across

[19] In all simulations, firms are symmetric ($s_{ij} = s_j$). Statistics for the model with ex-ante identical sectors (*one-sector model*) are solved analytically, with derivations provided in Appendix B.3. Statistics for the *multi-sector model* are solved numerically, as detailed in Appendix B.4.

[20] 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 markup level implies $\ln(\mu^{new}) = 0.409$. Assuming the same elasticity of substitution, this implies $\varphi^{new} = 0.728$ and thus $1/(1 + \varphi^{new}) = 0.58$.

Table 4: Statistics in multi-sector oligopoly model with sticky prices.

Statistic	Baseline MC(1) $(\lambda, \varphi = 0)$	× Relative to Baseline OC(1) (λ, φ)	MC(J) $(\lambda_j, \varphi = 0)$	OC(J) (λ_j, φ)	OC(J) (λ_j, φ_j)
	(1)	(2)	(3)	(4)	(5)
(a) 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
(b) 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

Notes: The table provides model statistics based on weighted estimates from NAPCS7 products (panel a) and NAICS4 industries (panel b). The first row of each panel reports the cumulative response of aggregate output (in %) to an unanticipated permanent 1% increase in money supply. The second row of each panel reports price stickiness λ 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 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 λ is set to the weighted mean price stickiness in the data and $\varphi = 0.43$. Column (3) reports statistics for a 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.

sectors—while keeping strategic complementarity the same across sectors—the slope of NKPC is reduced by an additional 30% relative to the one-sector OC model, resulting in 60% flatter NKPC relative to the baseline model. This amplification is due to interaction of nominal price rigidity and strategic complementarity across sectors pointed out by Carvalho (2006). Most price adjustments after the monetary shock are made by firms in more flexible sectors. As time passes by, a larger proportion of prices that are yet to adjust are from stickier sectors, slowing the aggregate price adjustment. Even without strategic complementarity ("MC(J)", column 3), such frequency composition effect reduces the slope of NKPC by 44%. Adding strategic complementarity (column 4), reduces price changes by adjusting firms, further dampening the aggregate price response and reducing the NKPC slope by an additional 16 percentage points.

Finally, we match both price stickiness and strategic complementarity implied by idiosyncratic cost pass-through estimated for each sector (column 5). As we documented in Section 4.2, sectors with lower idiosyncratic cost pass-through (i.e., stronger strategic complementarity) tend to have stickier prices. This means that amplification of price stickiness by strategic complementarity is stronger for sectors with stickier prices. This interaction between price stickiness and strategic complementarity flattens the NKPC slope by an additional 14 percentage points. This is a conservative estimate since we assumed strategic pricing complementarity only *within* sectors, and there are no strategic interactions *across* sectors. As Carvalho (2006) explained, when prices are strategic complements across sectors, price changes by firms in more flexible sectors are influenced by prices in sticky sectors, further slowing aggregate price adjustment.

(a) Price reduction due to sectoral heterogeneity   (b) Output response

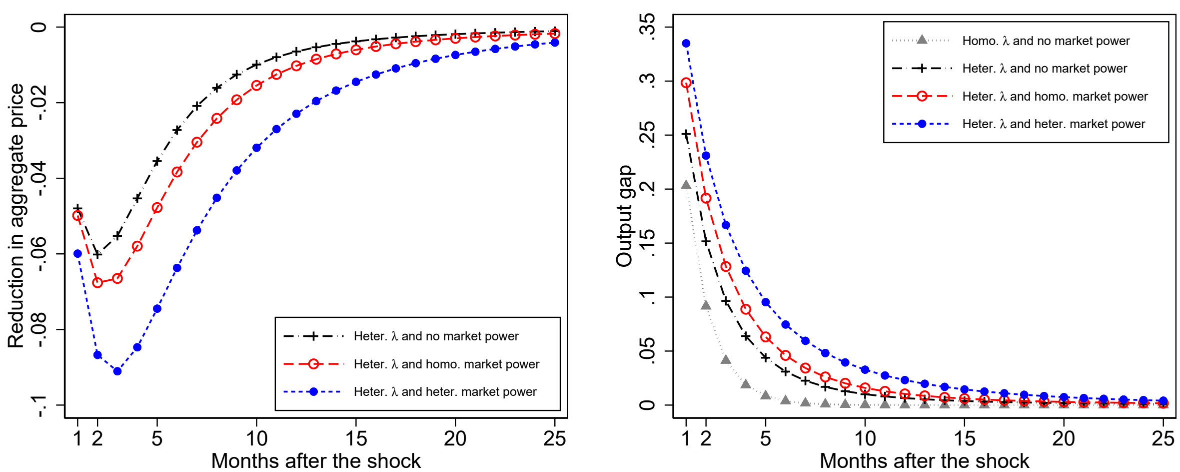


Figure 7: Amplification due to strategic complimentarity in multi-sector oligopoly model

Notes: Figure provides responses to an unanticipated permanent 1% increase in money supply. Panel (a) reports the difference between the aggregate price response and the response in the baseline MC(1) model. Panel (b) reports output impulse responses. Models are based on weighted estimates from NAPCS7 products.

Figure 7 shows how incorporating heterogeneity of price stickiness and strategic complementarity dampens the aggregate price response relative to the response in the baseline model (Panel a) and amplifies corresponding output responses (Panel b). Relative to the MC(1) baseline, the output response is amplified by 1.47 in the model with heterogeneity in price stickiness, by 1.84 when there is homogeneous strategic complementarity due to oligopolistic competition, and by 2.38 when both strategic complementarity and price stickiness vary across sectors. One could approximate these effects using standard one-sector Calvo model in which nominal price stickiness λ is increased by a factor of 1.21, 1.33, and 1.47, respectively.

In sum, our empirical estimates imply a substantial degree of strategic pricing complementarity in oligopolistic markets. The slope of NKPC in the multi-sector model that matches heterogeneity in price stickiness and strategic complementarity is only one-forth of the slope in the standard one-sector model without real ridigities. Out of the 74% difference in the slope, 30 percentage points is due to the average effect of oligopolistic competition (without sector heterogeneity), additional 30 percentage points is due to heterogeneity in price stickiness, and the remaining 14 percentage points captures (conservatively) 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 74% 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 variation in price flexibility during such events (Montag and Villar, 2023), one needs to incorporate *endogenous* price flexiblity 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.

References

Altig, David, Lawrence J. Christiano, Martin Eichenbaum, and Jesper Lindé. 2011. "Firm-specific capital, nominal rigidities and the business cycle." *Review of Economic Dynamics*, 14(2): 225–247.

Alvarez, Fernando, Francesco Lippi, and Panagiotis Souganidis. 2023. "Price Setting With Strategic Complementarities as a Mean Field Game." *Econometrica*, 91(6): 2005–2039.

Amiti, Mary, Oleg Itskhoki, and Jozef Konings. 2019. "International Shocks, Variable Markups, and Domestic Prices." *Review of Economic Studies*, 86(6): 2356–2402.

Anderson, Eric, Sergio Rebelo, and Arlene Wong. 2018. "Markups Across Space and Time." National Bureau of Economic Research, Inc NBER Working Papers 24434.

Atkeson, Andrew, and Ariel Burstein. 2008. "Pricing-to-Market, Trade Costs, and International Relative Prices." *American Economic Review*, 98(5): 1998–2031.

Auer, Raphael A., and Raphael S. Schoenle. 2016. "Market structure and exchange rate pass-through." *Journal of International Economics*, 98: 60–77.

Baqaee, David, Emmanuel Farhi, and Kunal Sangani. 2021. "The Supply-Side Effects of Monetary Policy." National Bureau of Economic Research Working Paper 28345.

Basu, Susanto. 1995. "Intermediate Goods and Business Cycles: Implications for Productivity and Welfare." *The American Economic Review*, 85(3): 512–531.

Berger, David, Jon Faust, John H. Rogers, and Kai Steverson. 2012. "Border prices and retail prices." *Journal of International Economics*, 88(1): 62–73.

Burstein, Ariel, Martin Eichenbaum, and Sergio Rebelo. 2005. "Large Devaluations and the Real Exchange Rate." *Journal of Political Economy*, 113(4): 742–784.

Burstein, Ariel T, Joao C Neves, and Sergio Rebelo. 2003. "Distribution Costs and Real Exchange Rate Dynamics During Exchange-rate-based Stabilizations." *Journal of monetary Economics*, 50(6): 1189–1214.

Burstein, Ariel, Vasco M Carvalho, and Basile Grassi. 2020. "Bottom-up markup fluctuations." National Bureau of Economic Research.

Calvo, Guillermo A. 1983. "Staggered Prices in a Utility-maximizing Framework." *Journal of Monetary Economics*, 12(3): 383–398.

Carvalho, Carlos. 2006. "Heterogeneity in Price Stickiness and the Real Effects of Monetary Shocks." *The B.E. Journal of Macroeconomics*, 6(3): 1–58.

Corsetti, Giancarlo, and Luca Dedola. 2005. "A macroeconomic model of international price discrimination." *Journal of International Economics*, 67(1): 129–155.

De Loecker, Jan, Jan Eeckhout, and Gabriel Unger. 2020. "The Rise of Market Power and the Macroeconomic Implications." *The Quarterly Journal of Economics*, 135(2): 561–644.

di Giovanni, Julian, Andrei A Levchenko, and Isabelle Méjean. 2014. "Firms, Destinations, and Aggregate Fluctuations." *Econometrica*, 82(4): 1303–1340.

Dotsey, Michael, and Robert G. King. 2006. "PRICING, PRODUCTION, AND PERSISTENCE." *Journal of the European Economic Association*, 4(5): 893–928.

Edmond, Chris, Virgiliu Midrigan, and Daniel Yi Xu. 2015. "Competition, Markups, and the Gains from International Trade." *American Economic Review*, 105(10): 3183–3221.

Eichenbaum, Martin, Nir Jaimovich, and Sergio Rebelo. 2011. "Reference Prices, Costs, and Nominal Rigidities." *American Economic Review*, 101(1): 234–62.

Fujiwara, Ippei, and Kiminori Matsuyama. 2022. "Competition and the Phillips curve." *Centre for Economic Policy Research.*

Ganapati, Sharat. 2024. "The Modern Wholesaler: Global Sourcing, Domestic Distribution, and Scale Economies." National Bureau of Economic Research, Inc NBER Working Papers 32036.

Goldberg, Linda S, and José Manuel Campa. 2010. "The Sensitivity of the CPI to Exchange Rates: Distribution Margins, Imported Inputs, and Trade Exposure." *The Review of Economics and Statistics*, 92(2): 392–407.

Goldberg, Pinelopi Koujianou, and Rebecca Hellerstein. 2012. "A Structural Approach to Identifying the Sources of Local Currency Price Stability." *The Review of Economic Studies*, 80(1): 175–210.

Gopinath, Gita, and Oleg Itskhoki. 2010. "Frequency of Price Adjustment and Pass-Through*." *The Quarterly Journal of Economics*, 125(2): 675–727.

Gopinath, Gita, and Oleg Itskhoki. 2011. "In Search of Real Rigidities." In *NBER Macroeconomics Annual 2010.* ed. Daron Acemoglu and Michael Woodford, Chapter 5. National Bureau of Economic Research.

Gopinath, Gita, Pierre-Olivier Gourinchas, Chang-Tai Hsieh, and Nicholas Li. 2011. "International Prices, Costs, and Markup Differences." *American Economic Review*, 101(6): 2450–2486.

Höynck, Christian, Minghao Li, and Donghai Zhang. 2022. "The Markup Elasticity of Monetary Non-Neutrality." *Available at SSRN 4283059.*

Kimball, Miles. 1995. "The Quantitative Analytics of the Basic Neomonetarist Model." *Journal of Money, Credit and Banking*, 27(4): 1241–77.

Klenow, Peter J., and Oleksiy Kryvtsov. 2008. "State-Dependent or Time-Dependent Pricing: Does it Matter for Recent U.S. Inflation?" *The Quarterly Journal of Economics*, 123(3): 863–904.

Mongey, Simon. 2021. "Market Structure and Monetary Non-neutrality." National Bureau of Economic Research Working Paper 29233.

Montag, Hugh, and Daniel Villar. 2023. "Price-Setting During the Covid Era." Board of Governors of the Federal Reserve System (U.S.) FEDS Notes 2023-08-29.

Nakamura, Emi, and Dawit Zerom. 2010. "Accounting for Incomplete Pass-Through." *Review of Economic Studies*, 77(3): 1192–1230.

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

Nakamura, Emi, and Jon Steinsson. 2013. "Price Rigidity: Microeconomic Evidence and Macroeconomic Implications." *Annual Review of Economics*, 5(1): 133–163.

Nakamura, Emi, and Jón Steinsson. 2010. "Monetary Non-neutrality in a Multisector Menu Cost Model*." *The Quarterly Journal of Economics*, 125(3): 961–1013.

Neiman, Brent. 2011. "A State-dependent Model of Intermediate Goods Pricing." *Journal of International Economics*, 85(1): 1–13.

Ueda, Kozo. 2023. "Duopolistic Competition and Monetary Policy." *Journal of Monetary Economics*, 135: 70–85.

Ueda, Kozo, and Kota Watanabe. 2023. "Oligopolistic Competition, Price Rigidity, and Monetary Policy."

Wang, Olivier, and Iván Werning. 2022. "Dynamic Oligopoly and Price Stickiness." *American Economic Review*, 112(8): 2815–49.

A Data Appendix

A.1 Data Cleaning Process

Our empirical analysis relies on two raw micro datasets. The first is the monthly WSPI price micro data file. This includes information on monthly wholesale purchase prices and selling prices for individual firm-products. It also includes other information we use in our analysis and to inform the cleaning process. The second dataset is the weights file, which is developed to be merged with the WSPI price file for the purpose of providing a representative sample to construct the WSPI. We discuss more details about both these files below.

The raw micro data has not been cleaned prior to our receiving the data, and none of the prices in our data are imputed. Prior to constructing the WSPI, Statistics Canada conducts various error detection tests and excludes some outliers and anomalies in the data. More generally, Statistics Canada dedicates resources to ensuring any reported price changes in the survey are not contaminated by any structural changes to the product definition, including product re-classifications or changes in units. The survey's data collection strategy is designed to ensure that targeted response rates are met every cycle, and the survey receives about a 75% response rate. Following this, an imputation process is undertaken to achieve 100% coverage for the published price index.

The survey is stratified by NAICS5 code. The largest establishments in a given NAICS industry are selected as "take-all" (100% probability), with remaining establishments selected with probabilities that are proportional to their revenue. To construct the index, individual respondents are assigned weights based on establishment revenues and industry gross margins, to arrive at a representative sample of wholesale sector prices. New survey participants are introduced to the survey through telephone calls, where respondents are guided through a process of selecting representative products. The data are updated (and revised) quarterly, where respondents are asked to answer the survey based on information from the preceding three months. The sample of respondents for the price file is updated roughly every five years. The weights file is updated along with the sample update, roughly every five years. The sample used for this analysis was last updated in May 2023.

The price file includes several variables that correspond in some fashion to firm/establishment/firm-product identifiers: (1) the "PID" is intended to uniquely identify each firm-product in the data. It assigned by the PPD based on the Generic Processing System (GPS) and serves as our primary unit of analysis in the paper; (2) the "PPDID" is assigned by the PPD and is intended to correspond one-to-one with the establishment level on Statistics Canada's Business Register (BR). The PPDID is the sampling unit for the WSPI survey; (3) the "Operating Entity Number" is also intended to correspond one-to-one with the establishment level, and is taken directly from value reported in the BR; and (4) the "Enterprise Number" is intended to correspond one-to-one with the enterprise level and is taken directly from value reported in the BR.[21] Also included are classification codes for the NAICS5 industry that the reporting firm is associated with and the NAPCS7 product code that the firm-product is associated with.

The price file also includes information on the country of origin of the product, the currency that product prices are reported in, and several flags that help to ascertain the quality of the data. There are two variables that provide information on the country of origin of the product. One is an "imported" binary variable that takes the value of 1 if imported and 0 if not imported. The second is an "origin" variable that takes different values that each correspond to a specific country of origin. In terms of currency, there are separate "currency of purchase price" and "currency of selling price" variables included in the data. In terms of flags, there is a "product hhange" flag that identifies cases where the product name appears to change, a"non comparable" flag that identifies where the series appears to have changed in a significant way that is suggests a break in the series, and an "exclude" flag that identifies outlier observations, based on the patterns observed in that particular firm-product over the periods around that observation. The "non comparable" and "exclude" flags also have associated variables that provide the reason for these flags based on a defined set of possible reasons. All these these flags are introduced by analysts in the PPD and not entered by the survey respondents.

The price file sample that we use begins in January 2013. The data are currently available up to 2023, but we drop all observations past December 2019 to exclude the COVID-19 pandemic period.

[21] An "enterprise" (also referred to as a "firm") is defined as an institutional unit that directs and controls the allocation of resources relating to business operations, and for which financial statements are maintained. An "establishment" (also known referred to as a "plant") is below the enterprise in the statistical hierarchy and is defined as the most homogeneous unit of production for which the business maintains accounting records.

The weights file includes two sub-files: one for the 2013 reference period (released in the second quarter of 2016) and one for the 2020 reference period (released in the third quarter of 2022). Each weight in a given file is intended to correspond uniquely to a single PPDID in the corresponding WSPI price file. However, there are cases where a single PPDID is reported in both sampling periods, so that one PPDID has a weight reported in each weight file. In these cases, we use the weight from the older weight sample. In some cases the weight is missing in one weight sample available in the other. In these cases, we use the weight that is available. This files includes several weights that we use. 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.[22] The second is a "design weight," equal to the inverse of the firm's selection probability, induced by the sample design. This weight can be interpreted as the number of times that each sampled establishment 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, and represents the relative importance of the establishment in the industry, and is used to construct an index that is representative of the aggregate.

Once the WSPI price file is merged with with the weights file, we initially apply a few small cleaning procedures. In terms of hierarchical structure, a single enterprise might nest several establishments, but a single establishment should not nest several enterprises. So, we drop cases where multiple Enterprise Numbers are associated with a single Operating Entity Number or PPDID. The PPDID and the Operating Entity Number are supposed to map one-to-one with one another, so we also drop cases where this mapping is not one-to-one. Once that procedure is applied, we are left with roughly 420,000 observations.

From there, we identify cases where the "imported" variable is 0 but the "origin" variable indicates a foreign origin. We assume the "origin" variable is correct and re-code the "imported" variable to 1. Also, in cases where the "imported" variable is missing, we assume the good is not imported and re-code the variable to 0. We drop observations where the currency of the reported selling or purchase price is in a currency of than Canadian dollars, US dollars or Euros.[23] In cases

[22] The revenue weight corresponds one-to-one with the wholesale establishment level.
[23] Note that this only affects a small number of observations.

where the currency reported is either US dollars or Euros, we apply the bilateral monthly exchange rate and convert the price into Canadian dollars. We also drop cases where the firm-product margin is less than 1, indicating that the selling price is lower than the purchase price, and drop observations where the selling price or purchase price changes by more than 100% from between consecutive months. We drop cases where a single PID is reported for only one period in the data.

For cases where the "product change" flag is one, we reclassify product so that a new PID is assigned. We drop observations where there is an "exclude" flag and cases where there is a "non comparable" but not a "product change" flag (since these are reclassified as new products). We also drop observations where the selling price or purchase prices is either missing or zero, and where the establishment revenue weight is either missing or non-positive.

After all of these changes, we are left with roughly 280,000 observations in the cleaned sample.[24]

A.2 Additional Descriptions of the Data

The breakdown of the average number of products per firm across periods in our cleaned sample is reported in Table A1. We product this this by constructing a new variable equal to the number of PIDs associated with each PDDID per period, and then tabulating the share of this variable in the total sample that falls under 1, 2, 3, 4, and 5+.

Table A1: Number of products per firm in cleaned WSPI sample

	1	2	3	4	5+
Share of firms	9%	15%	67%	3%	6%

Our sample covers 90 months, from January 2013 to December 2019. Table A2 reports the number of observation per firm-product, calculated by creating a new variable that is equal to the number of observations per PID in the sample, and then classifying each PID according to which bin this number falls into (e.g., 1-20, 20-40, etc.). As depicted in the table, 75% of products include more than 20 observation months. This feature of the data is attractive in that most of our analysis will rely on product-level cross-time variation, and so a long sample period at the product level is desirable.

[24] Most of the roughly 140,000 observations that are dropped are removed due to missing prices.

Table A2: Number of observation months per firm-product in cleaned WSPI sample

	1-20	21-40	41-60	61-80	80-100
Share of observations	25%	24%	26%	20%	6%

Survey respondents are asked what currency the purchase price and selling price are reported in. Table A3 reports the share of observations in the cleaned dataset that are reported in Canadian dollars and US dollars. Roughly 96% (97%) percent of respondents report purchase (selling) prices in Canadian dollars, and nearly all the rest report in US dollars. In cases where the currency reported is either US dollars or Euros, we apply the bilateral monthly exchange rate and convert the price into Canadian Dollars.

Table A3: Currency of prices reported in cleaned WSPI sample, shares

	Purchase prices	Selling prices
Canadian dollar	0.96	0.97
US dollar	0.04	0.03

In terms of the origin of the products reported in the data, we can group products into three different types: domestic goods, goods imported from the US, and goods imported from non-US countries. In aggregate sample, 44% of goods originate from the domestic economy, 32% originate from the US, and the remaining 25% originate from other countries (non-US). This breakdown, however, is different from industry to industry. Figure A1 reports the breakdown separately for each NAICS3 industry, where the heterogeneity is clear. For example, the domestic economy is the top source of goods in most industries, but the US is the most common origin for goods in the "Machinery, equipment and supplies" industry, and non-US foreign economies are the most common origin for goods in the "Personal and household goods" industry. This heterogeneity provides one foundation for heterogeneity in exposure to shocks across industries. For example, industries that are more reliant on imported goods would be more exposed to exchange rate shocks and foreign common shocks.

Figure A2 reports the average size of purchase and selling price changes in the sample for each NAICS3 industry. The cross-industry heterogeneity in this figure is fairly similar to the pattern

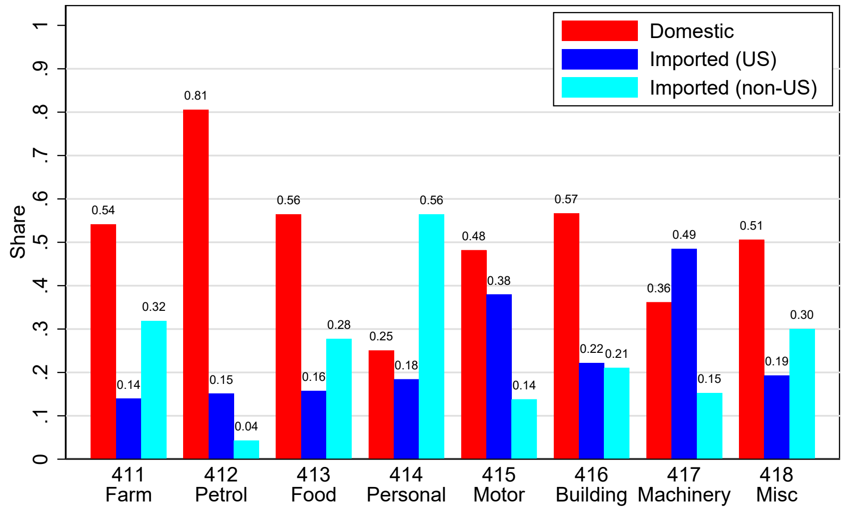


Figure A1: Origin of products, by 3-digit NAICS wholesale industry

Notes: Reports the design-weighted mean of product origins across all observations in the sector.

observed in Figure 2, which reports the average fraction of price changes across industries. The average size of price change is equal to the average fraction of price changes times the size of price change conditional on adjustment, so the positive correlation here indicates that the fraction of price adjustments plays a large role in determining average prices changes.

Figure A3 reports a histogram for the (log) margin across firm-products in our cleaned sample. The important thing to note is that the distribution is far from uniform, indicating a high degree of heterogeneity.

Our analysis relies on firm and product classifications according to NAICS4 industry codes and NAPCS7 product codes. The firms surveyed for the WSPI are each classified to a single NAICS code under the 2-digit "Wholesale Trade" industry (NAICS 41). The complete list of 25 NAICS4 codes under NAICS 41 (i.e., the set of codes assigned to the firms in the WSPI survey) is reported in Table A4. Each firm-product is assigned to a single NAPCS7 product code under the 3-digit product group "Wholesale services (except commissions)" (NAPCS 551). Our cleaned dataset includes 166 NAPCS7 codes under NAPCS 551 (i.e., the set of codes assigned to the products in the WSPI survey). See link for the complete list of NAPCS product codes.

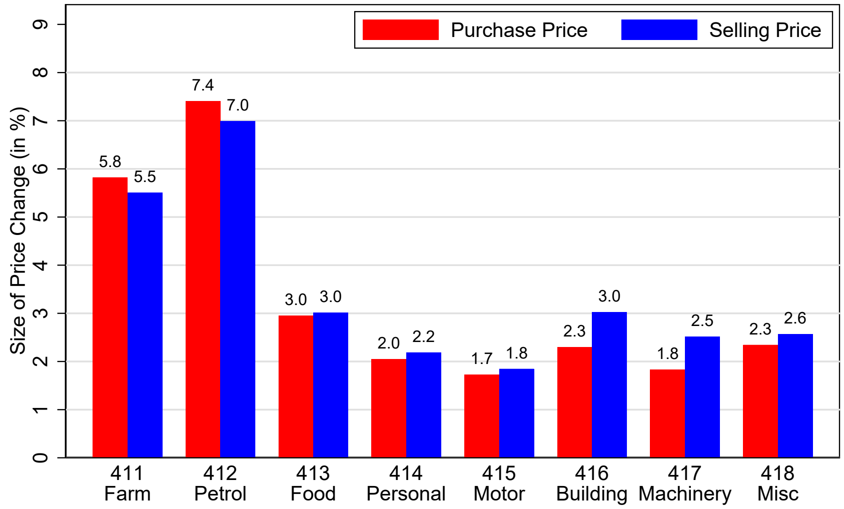


Figure A2: Average size of price changes, by 3-digit NAICS wholesale industry

Notes: Reports the design-weighted mean size of price changes across all observations in the sector.

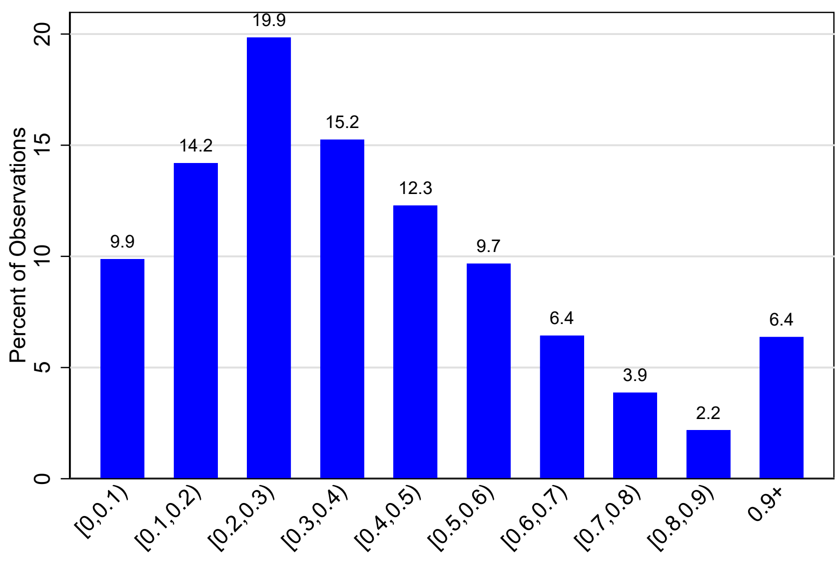


Figure A3: Histogram of margin across firm-products, pooled sample

Notes: Reports the design-weighted distribution of margins across firm-products in the sample.

(a) 4-digit NAICS wholesale industry level (b) 7-digit NAPCS wholesale product level

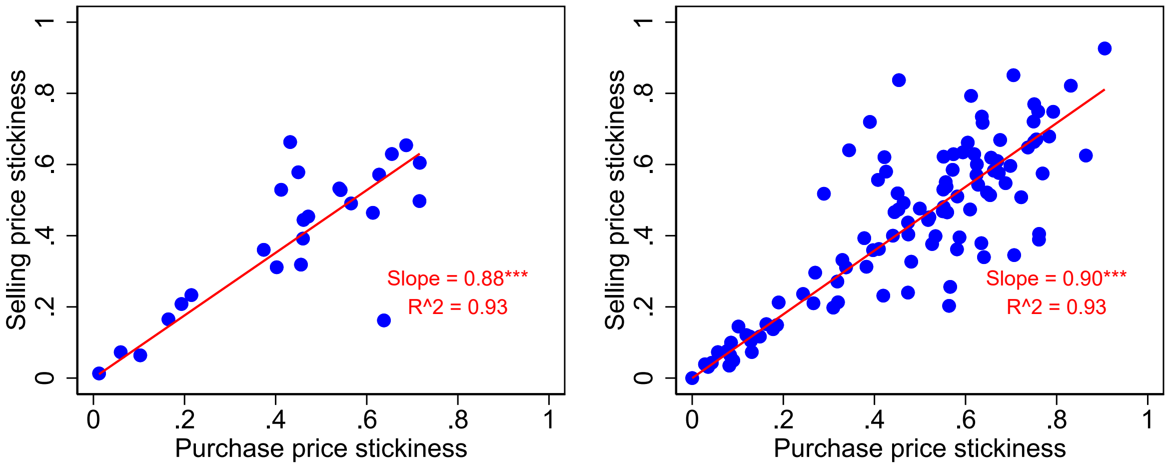


Figure A4: Selling and purchase price synchronization at the industry and product levels (weighted)

Table A4: 4-digit NAICS wholesale industries

NAICS	Industry Description
4111	Farm product merchant wholesalers
4121	Petroleum and petroleum products merchant wholesalers
4131	Food merchant wholesalers
4132	Beverage merchant wholesalers
4133	Cigarette and tobacco product merchant wholesalers
4134	Cannabis merchant wholesalers
4141	Textile, clothing and footwear merchant wholesalers
4142	Home entertainment equipment and household appliance merchant wholesalers
4143	Home furnishings merchant wholesalers
4144	Personal goods merchant wholesalers
4145	Pharmaceuticals, toiletries, cosmetics and sundries merchant wholesalers
4151	Motor vehicle merchant wholesalers
4152	New motor vehicle parts and accessories merchant wholesalers
4153	Used motor vehicle parts and accessories merchant wholesalers
4161	Electrical, plumbing, heating and air-conditioning equipment and supplies merchant wholesalers
4162	Metal service centres
4163	Lumber, millwork, hardware and other building supplies merchant wholesalers
4171	Farm, lawn and garden machinery and equipment merchant wholesalers
4172	Construction, forestry, mining, and industrial machinery, equipment and supplies merchant wholesalers
4173	Computer and communications equipment and supplies merchant wholesalers
4179	Other machinery, equipment and supplies merchant wholesalers
4181	Recyclable material merchant wholesalers
4182	Paper, paper product and disposable plastic product merchant wholesalers
4183	Agricultural supplies merchant wholesalers
4184	Chemical (except agricultural) and allied product merchant wholesalers
4189	Other miscellaneous merchant wholesalers

A.3 Measures of price stickiness and market power

Measures of the average degree of price stickiness are constructed as follows:[25]

$$\lambda_j = 1 - \frac{1}{2}\frac{\sum_{i\in I_j}\sum_{t\in T_{ij}}\omega_{ij}^E\left\{\mathbb{1}\left[\Delta\ln(P_{ijt})\neq 0\right]+\mathbb{1}\left[\Delta\ln(Q_{ijt})\neq 0\right]\right\}}{\sum_{i\in I_j}\sum_{t\in T_{ij}}\omega_{ij}^E}, \quad \text{(Sector price stickiness)}$$

$$\lambda_{fj} = 1 - \frac{1}{2}\frac{\sum_{i\in I_f}\sum_{t\in T_{ij}}\omega_{ij}^E\left\{\mathbb{1}\left[\Delta\ln(P_{ijt})\neq 0\right]+\mathbb{1}\left[\Delta\ln(Q_{ijt})\neq 0\right]\right\}}{\sum_{i\in I_f}\sum_{t\in T_{ij}}\omega_{ij}^E}, \quad \text{(Firm price stickiness)}$$

$$\lambda_{ij} = 1 - \frac{1}{2}\frac{\sum_{t\in T_{ij}}\left\{\mathbb{1}[\Delta\ln(P_{ijt})\neq 0]+\mathbb{1}\left[\Delta\ln(Q_{ijt})\neq 0\right]\right\}}{\sum_{t\in T_{ij}}\mathbb{1}}, \quad \text{(Firm-product price stickiness)}$$

where I_j and I_f denote the sets of firm-product observations in industry j and in firm f, respectively; T_{ij} denotes the set of months for which a price change from the previous month is observed for firm-product i in industry j; and ω_{ijt}^E is the economic weight of the firm, calculated as the establishment revenue of the firm divided by the probability of selection. Intuitively, price stickiness is equal to 1 minus the average monthly fraction of adjusting prices at a sector, firm or product level. As we discussed in Section 3, the selling price stickiness is very similar to the purchase purchase stickiness for most sectors and products. We take the average of the two measures to account for the small discrepancy in some industries.

Unlike price stickiness, the market power of a firm is not directly observed in the data. According to most models of imperfect competition, price markup is a suitable proxy for market power. In our model, market power, summarized by strategic complementarity φ_{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 θ:

$$\varphi_{ij} = \left(\frac{\theta-1}{\theta}\mu_{ij}-1\right)(\theta-1)$$

We exploit distributor's margin as the proxy for price markup to construct two dummies that

[25] As discussed in Section 3, the degree of selling price stickiness is highly correlated with that of purchase price stickiness. Using the purchase price stickiness measures yields similar results.

capture the variation in market power across and within sectors:

$$D_j = \begin{cases} 1 & \text{if } \mu_j \in \text{upper quartile of } \{\mu_j\} \text{ across all sectors,} \\ 0 & \text{otherwise,} \end{cases} ,$$

$$D_{ij} = \begin{cases} 1 & \text{if } \mu_{ij} \in \text{upper quartile of } \{\mu_{ij}\} \text{ among all } i \in I_j, \\ 0 & \text{otherwise,} \end{cases} ,$$

where $\mu_j = \frac{\sum_{i \in I_j} \sum_{t \in T_{ij}} \omega_{ij}^E \mu_{ijt}}{\sum_{i \in I_j} \sum_{t \in T_{ij}} \omega_{ij}^E}$ is the weighted mean margin across all firm-product observations in sector j,[26] and μ_{ij} is the average margin of firm-product i. $D_j = 1$ identifies the top quartile of high-markup sectors, and $D_{ij} = 1$ defines the top quartile of high-markup firms in sector j.

[26] Conditioning on observations with price changes yields similar average sector margins. Intuitively, if cumulative positive and negative cost shocks over the firm-product's price duration are roughly equal, the conditional and unconditional sector margins are similar.

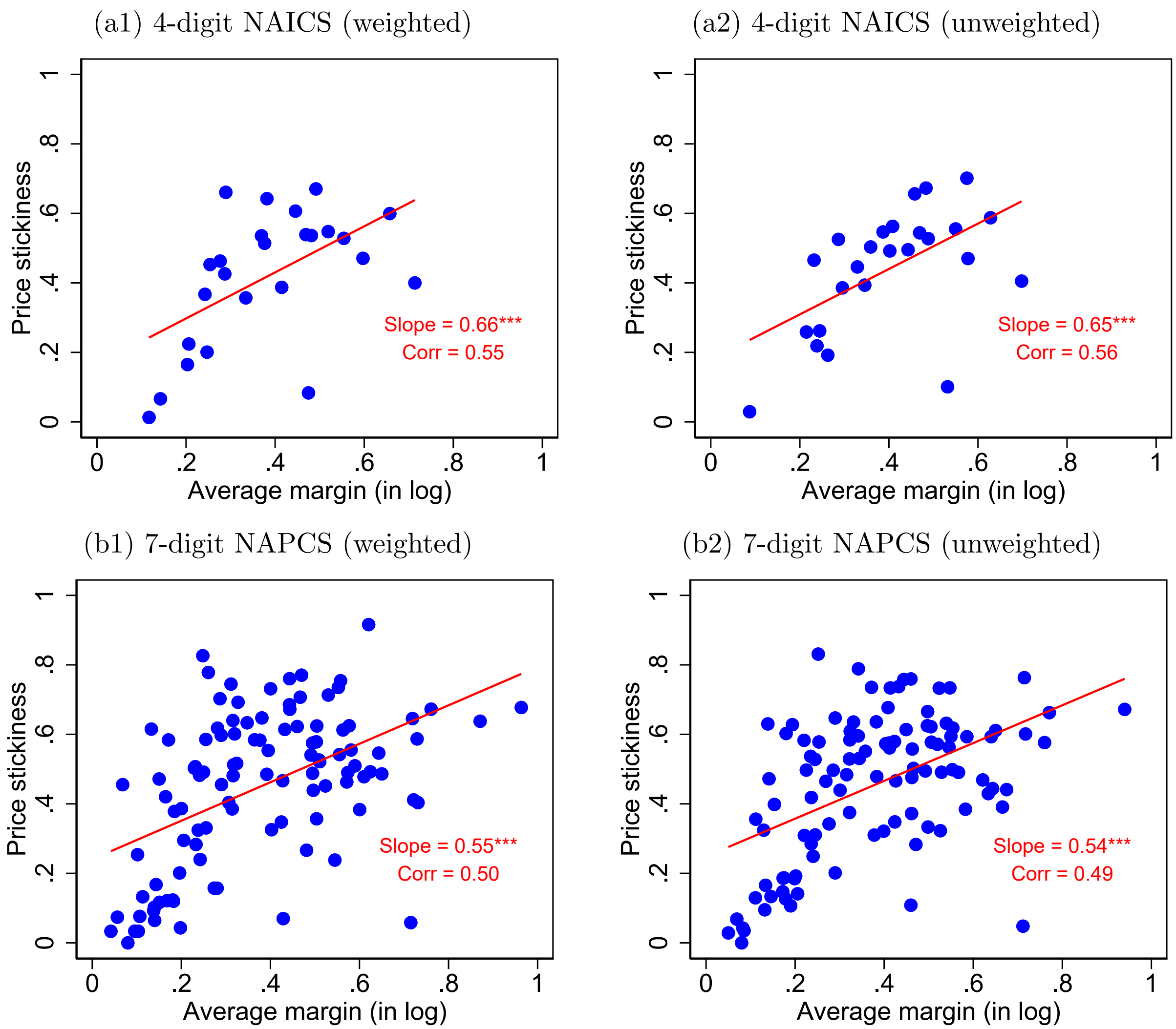


Figure A5: Correlation between price stickiness and average margin

Notes: The figures illustrate the the cross-industry correlation between the average price stickiness λ_j and the average margin μ_j, with measures calculated at NAICS4 and NAPCS7 levels respectively. The weighted measures constructed use the economic weight ω_{ij}^{E}.

A.4 Supplementary Estimation Results

Table A5: Pass-through estimates, 4-digit NAICS wholesale industries (unweighted)

	(1)	(2)	(3)	(4)	(5)	(6)
Common cost	0.76***	0.91***	0.91***	0.91***	0.96***	0.98***
	(0.028)	(0.038)	(0.038)	(0.038)	(0.031)	(0.023)
Idio. cost	0.69***	0.74***	0.74***	0.74***	0.75***	0.87***
	(0.017)	(0.048)	(0.048)	(0.048)	(0.04)	(0.036)
Common cost × Sectoral stickiness		-0.76***	-0.82***	-0.76***	-0.55***	-0.47***
		(0.119)	(0.135)	(0.126)	(0.11)	(0.098)
Idio. cost × Sectoral stickiness		-0.10	-0.04	-0.04	-0.03	-0.10
		(0.112)	(0.118)	(0.116)	(0.101)	(0.093)
Common cost × Firm stickiness			0.16			
			(0.16)			
Idio. cost × Firm stickiness			-0.16**			
			(0.058)			
Common cost × Firm-product stickiness				0.05		
				(0.144)		
Idio. cost × Firm-product stickiness				-0.19***		
				(0.056)		
Common cost × High-margin industry					-0.37***	-0.35***
					(0.054)	(0.052)
Idio. cost × High-margin industry					-0.22***	-0.21***
					(0.044)	(0.042)
Common cost × High-margin firm						-0.14**
						(0.053)
Idio. cost × High-margin firm						-0.29***
						(0.037)
Observations	136,085	136,085	136,085	136,085	136,085	136,085
Firm-product fixed effects	✓	✓	✓	✓	✓	✓
R^2	0.48	0.48	0.48	0.48	0.49	0.5

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 margins. The dependent variable is the firm-product selling price. Estimates are based on monthly price data, are not weighted, 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. Statistical significance, based on robust standard errors clustered at the firm level, is reported at the 1, 5 or 10 percent level which is indicated by ***, **, or * respectively.

Table A6: Pass-through estimates, 7-digit NAPCS wholesale products (unweighted)

	(1)	(2)	(3)	(4)	(5)	(6)
Common cost	0.76***	0.82***	0.82***	0.82***	0.85***	0.90***
	(0.024)	(0.042)	(0.042)	(0.043)	(0.033)	(0.024)
Idio. cost	0.69***	0.68***	0.69***	0.69***	0.69***	0.80***
	(0.018)	(0.039)	(0.0390	(0.038)	(0.033)	(0.027)
Common cost × Sectoral stickiness		-0.26*	-0.31*	-0.26*	-0.18	-0.13
		(0.103)	(0.124)	(0.118)	(0.096)	(0.079)
Idio. cost × Sectoral stickiness		0.02	0.09	0.09	0.12	0.09
		(0.084)	(0.089)	(0.088)	(0.076)	(0.068)
Common cost × Firm stickiness			0.12			
			(0.101)			
Idio. cost × Firm stickiness			-0.21***			
			(0.061)			
Common cost × Firm-product stickiness				0.03		
				(0.085)		
Idio. cost × Firm-product stickiness				-0.24***		
				(0.059)		
Common cost × High-margin industry					-0.24*	-0.24**
					(0.096)	(0.085)
Idio. cost × High-margin industry					-0.22***	-0.23***
					(0.049)	(0.048)
Common cost × High-margin firm						-0.23***
						(0.036)
Idio. cost × High-margin firm						-0.31***
						(0.03)
Observations	133,620	133,620	133,620	133,620	133,620	133,620
Firm-product fixed effects	✓	✓	✓	✓	✓	✓
R^2	0.48	0.48	0.48	0.48	0.49	0.51

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 margins. The dependent variable is the firm-product selling price. Estimates are based on monthly price data, are bot weighted, 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 product-time fixed effect, where product is defined as the firm-product's NAPCS7 product code. Idiosyncratic shocks are defined as the residual of this first-stage regression. Statistical significance, based on robust standard errors clustered at the firm level, is reported at the 1, 5 or 10 percent level which is indicated by ***, **, or * respectively.

(a) Common PT against price stickiness

(b) Common PT against average margin

(c) Idiosyncratic PT against price stickiness

(d) Idiosyncratic PT against average margin

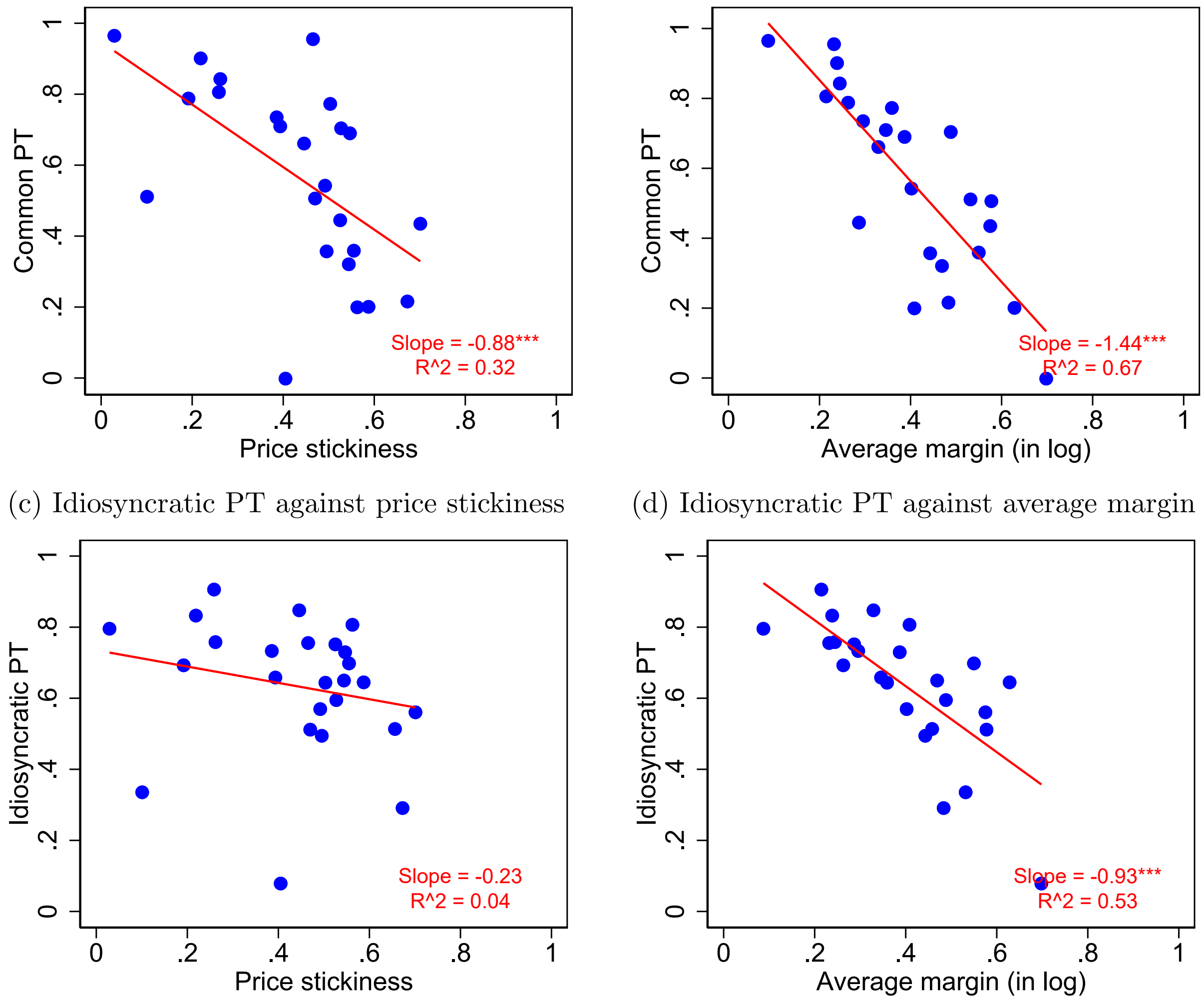
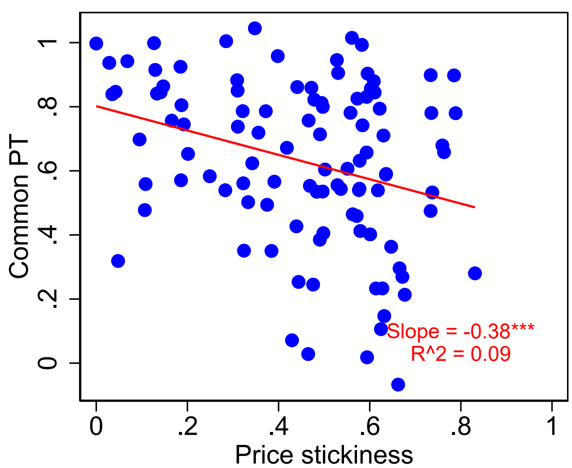
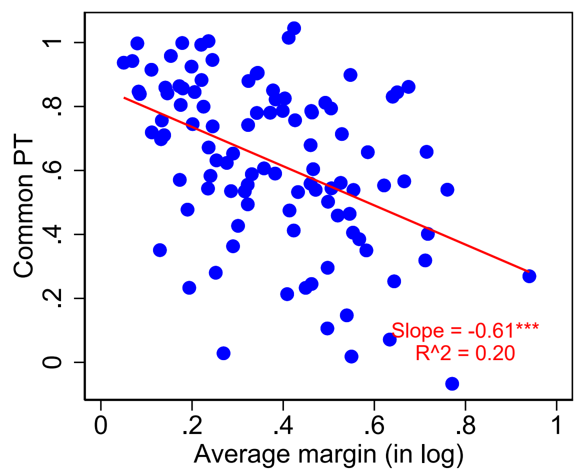


Figure A6: Estimates at the 4-digit NAICS wholesale industry level (unweighted)

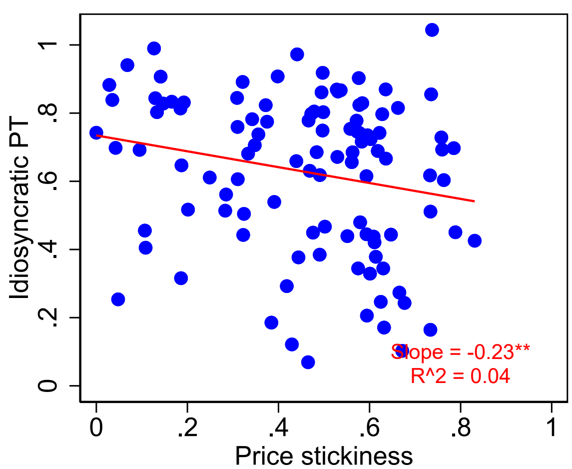
(a) Common PT against price stickiness



(b) Common PT against average margin



(c) Idiosyncratic PT against price stickiness



(d) Idiosyncratic PT against average margin

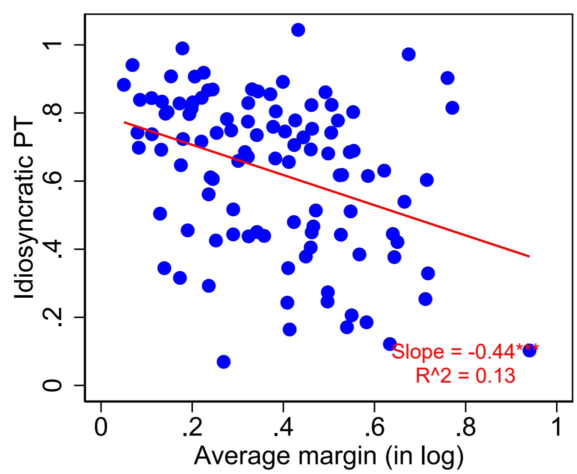


Figure A7: Estimates at the 7-digit NAPCS wholesale product level (unweighted)

Table A7: Variance decomposition of the pass-through rates

	4-digit NAICS		7-digit NAPCS	
	Stickiness λ_j	Margin μ_j	Stickiness λ_j	Margin μ_j
Common PT Φ_j	22.2%	30.4%	16.3%	16.7%
Idiosyncratic PT ϕ_j	26.7%†	55.0%	25.8%	37.4%

Notes: The table shows the contribution of price stickiness and average margin in explaining the cross-industry variance in the pass through rates, with measures defined at the NAICS4 industry and NAPCS7 product levels respectively. 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 $x_j \in \{\lambda_j, \mu_j\}$. † indicates the statistic is not different from zero at the 10% significance level.

Table A8: Variance decomposition of the pass-through rates (unweighted)

	4-digit NAICS		7-digit NAPCS	
	Stickiness λ_j	Margin μ_j	Stickiness λ_j	Margin μ_j
Common PT Φ_j	25.2%	37.9%	17.1%	19.0%
Idiosyncratic PT ϕ_j	19.6%†	57.2%	19.1%	28.5%

Notes: The table shows the contribution of price stickiness and average margin in explaining the cross-industry variance in the pass through rates, with measures defined at the NAICS4 industry and NAPCS7 product levels respectively. 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 $x_j \in \{\lambda_j, \mu_j\}$. † indicates the statistic is not different from zero at the 10% significance level.

A.5 Discussion of approximation of the marginal cost by the purchase price

Our baseline analysis assumes that the observed purchase price is a good proxy for the true marginal cost of the product sold. In the context of the wholesale industry, we believe this is a reasonable assumption. Nonetheless, in this subsection, we discuss the implications when this assumption no longer holds.

Consider a more general setting where the marginal cost of firm-product i in sector j, MC_{ijt}, comprises two components: (1) the observed purchase price Q_{ijt} and (2) the unobserved marginal cost component X_{ijt},

$$MC_{ijt} = Q_{ijt}^{\gamma} X_{ijt}^{1-\gamma} \quad \text{with} \quad \gamma \in (0, 1]. \tag{A.1}$$

Note that if the unobserved cost component X_{ijt} is highly correlated with the observed component, then the change in the observed purchase price $\widehat{Q}_{ijt}$ remains a good proxy for the change in the marginal cost $\widehat{MC}_{ijt}$. Taking an extreme case where these two variables are perfectly correlated, we have

$$\widehat{MC}_{ijt} = \gamma \widehat{Q}_{ijt} + (1-\gamma)\widehat{X}_{ijt} = \widehat{Q}_{ijt}. \tag{A.2}$$

The potential problem arises when the two cost components are not perfectly correlated. In the case where $Corr(\widehat{Q}_{ijt}, \widehat{X}_{ijt}) = a$, we have

$$\widehat{MC}_{ijt} = \gamma \widehat{Q}_{ijt} + (1-\gamma)\widehat{X}_{ijt} = [\gamma + (1-\gamma)a]\widehat{Q}_{ijt}. \tag{A.3}$$

In the model, firms reset prices according to their own and competitors' marginal costs. If the actual change in marginal cost is smaller than the observed purchase price change, then the pass-through will be less than 100%. In a standard monopolistic competition Calvo model, the pass-through rates to idiosyncratic ψ and common Ψ purchase price changes can be written as

$$\psi = \Psi = \gamma + (1-\gamma)a \leq 1. \tag{A.4}$$

Therefore, even without strategic complementarity, the measured pass-through to an idiosyncratic purchase price shock can be incomplete because the purchase price only accounts for a proportion of the true marginal cost. However, if this were true, the pass-through to the common purchase price shock would be the same as the pass-through to the idiosyncratic purchase price shock, which contradicts what we find in the data.

Through the lens of our oligopolistic competition Calvo model, the pass-through to a common purchase price shock in a *flexible price sector* is

$$\Psi = \gamma + (1 - \gamma)a. \tag{A.5}$$

Our empirical estimate of Ψ^{Est} is very close to 1, which implies $\gamma + (1 - \gamma)a \approx 1$. In other words, our empirical estimates suggest that the observed purchase price is a good proxy for the unobserved marginal cost in the wholesale industry.

B Model Appendix

B.1 General solutions when price changes are not synchronized with cost changes

We first solve for the firm's optimal reset price in response to both common and idiosyncratic cost shocks, without imposing the assumption of perfect synchronization in the timing of price and cost adjustments. We then demonstrate that Proposition 1 represents a special case of the solutions derived here. We begin by characterizing how the expected sectoral price reacts to an arbitrary set of firm-level cost shocks, which follow the same AR(1) process:

$$\widehat{Q}^*_{ijt} = \rho \widehat{Q}^*_{ijt-1} + \epsilon_{ijt} \tag{B.1}$$

where ϵ_{ijt} are *ex ante* mean zero shocks that can be correlated across firms. For example, a common (sectoral) shock occurs when $\epsilon_{ijt} = 1 \ \forall i \in j$, and an idiosyncratic shock occurs when $\epsilon_{ijt} = 1$ and $\epsilon_{kjt} = 0 \ \forall k \neq i \in j$.

We can re-express the sectoral Phillips curve (15) as a second-order difference equation in price levels:

$$\mathbb{E}_t \left[\widehat{P}_{jt+\tau} - \lambda \widehat{P}_{jt+\tau-1} - \beta\lambda(\widehat{P}_{jt+\tau+1} - \lambda \widehat{P}_{jt+\tau}) \right] = E_t \sum_i s_{ijt} \frac{(1-\beta\lambda)(1-\lambda)}{(1+\varphi_{ijt})} (\widehat{Q}^*_{ijt+\tau} + \varphi_{ijt} \widehat{P}_{jt+\tau}).$$

For any arbitrary set of realized shocks $\{\epsilon_{ijt}\}$ at t, the expected sectoral price at $t+\tau$ can be solved as

$$\mathbb{E}_t \widehat{P}_{jt+\tau} = \frac{\rho^{\tau+1} - \Lambda^{\tau+1}_{jt}}{\rho\,(1-b_{jt}) + \lambda\,[\beta\rho(\lambda-\rho) - 1]} a_{jt} \widehat{Q}^*_{jt} \quad \forall \tau \geq 0, \tag{B.2}$$

where

$$\Lambda_{jt} \equiv \frac{1}{2}\left[\lambda + \frac{1-b_{jt}}{\beta\lambda} - \sqrt{\left(\lambda + \frac{1-b_{jt}}{\beta\lambda}\right)^2 - \frac{4}{\beta}}\right], \tag{B.3}$$

$$a_{jt} \equiv \left(\sum_i \frac{(1-\beta\lambda)(1-\lambda)}{(1+\varphi_{ijt})} s_{ijt}\widehat{Q}^*_{ijt}\right)/\widehat{Q}^*_{jt} \quad \text{with} \quad \widehat{Q}^*_{jt} \equiv \sum_i s_{ijt}\widehat{Q}^*_{ijt}, \tag{B.4}$$

$$b_{jt} \equiv \sum_i s_{ijt}\frac{\varphi_{ijt}(1-\beta\lambda)(1-\lambda)}{(1+\varphi_{ijt})}. \tag{B.5}$$

Plugging the expected sectoral prices back into the firm's reset price (10), we have

$$\widehat{P}_{ijt,t} = \frac{1-\beta\lambda}{1+\varphi_{ijt}}\sum_{\tau=0}^{\infty}(\beta\lambda)^\tau\left[\rho^\tau\widehat{Q}_{ijt} + \varphi_{ijt}s_{ijt}\frac{\rho^{\tau+1}-\Lambda_{jt}^{\tau+1}}{\rho\,(1-b_{jt}) + \lambda\,[\beta\rho(\lambda-\rho)-1]}a_{jt}\widehat{Q}^*_{jt}\right].$$

Solving the geometric series gives

$$\widehat{P}_{ijt,t} = \frac{1-\beta\lambda}{(1-\beta\lambda\rho)(1+\varphi_{ijt})}\widehat{Q}^*_{ijt} + \frac{\varphi_{ijt}}{1+\varphi_{ijt}}\frac{\rho-\Lambda_{jt}}{1-\beta\lambda\Lambda_{jt}}\varkappa_{jt}\widehat{Q}^*_{jt}, \tag{B.6}$$

where

$$\varkappa_{jt} \equiv \frac{1-\beta\lambda}{1-\beta\lambda\rho}\frac{a_{jt}}{\rho\,(1-b_{jt}) + \lambda\,[\beta\rho(\lambda-\rho)-1]}. \tag{B.7}$$

Note that, under the case of symmetric firms and persistent shocks ($\rho = 1$), $\varkappa_{jt} = 1$.

We can rewrite (B.6) as responses to idiosyncratic and common (or average) cost shocks:

$$\widehat{P}_{ijt,t} = \underbrace{\frac{1-\beta\lambda}{(1-\beta\lambda\rho)(1+\varphi_{ijt})}}_{\text{PT to idiosyncratic shocks}}\left(\widehat{Q}^*_{ijt} - \widehat{Q}^*_{jt}\right) + \underbrace{\left[\frac{1-\beta\lambda}{(1-\beta\lambda\rho)(1+\varphi_{ijt})} + \frac{\varphi_{ijt}}{1+\varphi_{ijt}}\frac{\rho-\Lambda_{jt}}{1-\beta\lambda\Lambda_{jt}}\varkappa_{jt}\right]}_{\text{PT to common (or average) shocks}}\widehat{Q}^*_{jt} \tag{B.8}$$

Due to strategic interactions, the effects of a cost shock on a firm's optimal reset price can be decomposed into two distinct components: (1) the impact of the cost shock on the firm's optimal price holding the average cost of the industry fixed; and (2) the effect of changes in the industry's average cost in absence of idiosyncratic shocks.

Proof of Proposition 1 in the main text. When the timing of price adjustment is perfectly synchronized with that of the cost changes, the firm's expected future cost, when it has the opportunity to reset its price, is

$$\mathbb{E}_t[\widehat{Q}_{ijt+\tau,t}] = \widehat{Q}^*_{ijt} \quad \forall \tau \geq 0. \tag{B.9}$$

This turns out to be a special case of (B.8) with $\rho = 1$. Intuitively, with perfectly synchronized price and cost adjustments, the firm's cost is fixed over the period in which its price is fixed. Therefore, the optimal response is the same as that to a permanent cost shock:

$$\widehat{P}_{ijt,t} = \frac{1}{1+\varphi_{ijt}}\left(\widehat{Q}^*_{ijt} - \widehat{Q}^*_{jt}\right) + \left[\frac{1}{1+\varphi_{ijt}} + \frac{\varphi_{ijt}}{1+\varphi_{ijt}}\left(\frac{1-\Lambda_{jt}}{1-\beta\lambda\Lambda_{jt}}\right)\frac{a_{jt}}{1-b_{jt}+\lambda\left[\beta(\lambda-1)-1\right]}\right]\widehat{Q}^*_{jt}$$

■

B.1.1 Two underlying shock processes

In this subsection, we show a similar expression can be obtained when there are two underlying shock processes. Specifically, we allows for two different AR(1) processes for the common $\widehat{Q}^C_{jt}$ and idiosyncratic $\widehat{Q}^I_{ijt}$ components of the cost process $\widehat{Q}^*_{ijt}$, and arbitrary serial correlations in the residual terms ϵ_{jt} and ϵ_{ijt} of these two AR(1) processes:

$$\widehat{Q}^*_{ijt} = \widehat{Q}^I_{ijt} + \widehat{Q}^C_{jt} \tag{B.10}$$

$$\widehat{Q}^I_{ijt} = \rho^I_j \widehat{Q}^I_{ijt-1} + \epsilon_{ijt} \tag{B.11}$$

$$\widehat{Q}^C_{jt} = \rho^C_j \widehat{Q}^C_{jt-1} + \epsilon_{jt} \tag{B.12}$$

Note that, due to the limited number of firms in a sector, the idiosyncratic shocks ϵ_{ijt} may not sum to zero. As a result, we need to keep track of the evolution of both idiosyncratic and aggregate shocks in deriving the expected change in sectoral prices. The expression becomes more complicated:

$$\mathbb{E}_t \widehat{P}_{jt+\tau} = \frac{\Lambda_{1,jt}\Lambda_{2,jt}K_{jt+\tau}}{\lambda(\Lambda_{1,jt}-\rho_j^I)(\Lambda_{2,jt}-\rho_j^I)(\Lambda_{1,jt}-\rho_j^C)(\Lambda_{2,jt}-\rho_j^C)} \tag{B.13}$$

with

$$\begin{aligned} K_{jt+\tau} \equiv & -d_{jt}\widehat{Q}^C_{jt}(\rho_j^I)^\tau(\Lambda_{1,jt}-\rho_j^C)(\Lambda_{2,jt}-\rho_j^C) - a_{jt}\widehat{Q}^I_{jt}(\rho_j^C)^\tau(\Lambda_{1,jt}-\rho_j^I)(\Lambda_{2,jt}-\rho_j^I) \\ & + \Lambda_{1,jt}^\tau \left[\Lambda_{1,jt}\Lambda_{2,jt}(a_{jt}\widehat{Q}^I_{jt}\rho_j^I + (\Lambda_{1,jt}+\Lambda_{2,jt})(a_{jt}\widehat{Q}^I_{jt}\rho_j^C + d_{jt}\widehat{Q}^C_{jt}\rho_j^I) + a_{jt}\widehat{Q}^I_{jt}(\rho_j^C)^2 + d_{jt}\widehat{Q}^C_{jt}(\rho_j^I)^2\right] \end{aligned}$$

where

$$\begin{aligned} \Lambda_{1,jt} &\equiv \frac{1}{2}\left[\lambda + \frac{1-b_{jt}}{\beta\lambda} - \sqrt{\left(\lambda + \frac{1-b_{jt}}{\beta\lambda}\right)^2 - \frac{4}{\beta}}\right], \\ \Lambda_{2,jt} &\equiv \frac{1}{2}\left[\lambda + \frac{1-b_{jt}}{\beta\lambda} + \sqrt{\left(\lambda + \frac{1-b_{jt}}{\beta\lambda}\right)^2 - \frac{4}{\beta}}\right], \\ a_{jt} &\equiv \left(\sum_i \frac{(1-\beta\lambda)(1-\lambda)}{(1+\varphi_{ijt})} s_{ijt}\widehat{Q}^I_{ijt}\right)/\widehat{Q}^I_{jt} \quad \text{with} \quad \widehat{Q}^I_{jt} \equiv \sum_i s_{ijt}\widehat{Q}^I_{ijt}, \\ b_{jt} &\equiv \sum_i s_{ijt}\frac{\varphi_{ijt}(1-\beta\lambda)(1-\lambda)}{(1+\varphi_{ijt})}, \\ d_{jt} &\equiv \sum_i \frac{(1-\beta\lambda)(1-\lambda)}{(1+\varphi_{ijt})} s_{ijt}. \end{aligned}$$

Plugging (B.13) into equation (10), we can solve the optimal reset price as

$$\begin{aligned} \widehat{P}_{ijt,t} = & \frac{1-\beta\lambda}{(1-\beta\lambda\rho_j^I)(1+\varphi_{ijt})}(\widehat{Q}^I_{ijt} - \widehat{Q}^I_{jt}) + \left[\frac{1-\beta\lambda}{(1-\beta\lambda\rho_j^I)(1+\varphi_{ijt})} + \frac{\varphi_{ijt}}{1+\varphi_{ijt}}H_{jt}(\rho_j^I)a_{jt}\right]\widehat{Q}^I_{jt} \\ & + \left[\frac{1-\beta\lambda}{(1-\beta\lambda\rho_j^C)(1+\varphi_{ijt})} + \frac{\varphi_{ijt}}{1+\varphi_{ijt}}H_{jt}(\rho_j^C)d_{jt}\right]\widehat{Q}^C_{jt} \end{aligned} \tag{B.14}$$

where

$$H_{jt}(\rho) \equiv \frac{\Lambda_{1,jt}\Lambda_{2,jt}(1-\beta\lambda)}{\lambda(1-\Lambda_{1,jt}\beta\lambda)(\Lambda_{2,jt}-\rho)(1-\beta\lambda\rho)} = \frac{\rho - \Lambda_{jt}}{1-\beta\lambda\Lambda_{jt}}\varkappa_{jt}(\rho)/a_{jt} \tag{B.15}$$

Therefore, as in the single shock case, the optimal reset price response to the cost shocks can be decomposed into idiosyncratic (the first term of (B.14)) to common (the second and third terms of (B.14)) components. Note that the solution holds for any arbitrary realization of $\{\epsilon_{ijt}\}$ and ϵ_{jt} and does not require the shocks to be independent.

B.2 An example of homogeneous duopoly sectors

Figure B1 illustrates the evolution of sectoral and aggregate prices in a model with homogeneous duopoly sectors. Starting from the steady state at $t = 0$, we characterize the exact price dynamics in the model. As shown in the figure, at $t = 1$, there are four types of sectors based on the price adjustment patterns: (1) sectors where both firms adjusted their prices, denoted as $[A, A]$; (2) sectors where only the first firm adjusted its price, denoted as $[A, N]$; (3) sectors where only the second firm adjusted its price, denoted as $[N, A]$; and (4) sectors where neither firm adjusted their prices, denoted as $[N, N]$. The proportions of these sectors are given by $(1 - \lambda)^2$, $(1 - \lambda)\lambda$, $(1 - \lambda)\lambda$, and λ^2, respectively. It is evident that the *realization* of sectoral prices no longer follows Calvo due to the limited number of firms and the discrete realization of Calvo fairies in each sector. However, with large enough number of similar sectors, the evolution of the aggregate price can still be expressed in Calvo form as

$$\widehat{P}_1 = (1-\lambda)\widehat{P}_{1A} + \lambda\widehat{P}_{1N} = (1-\lambda)\left[(1-\lambda)\widehat{P}_{[A,A]} + \lambda\widehat{P}_{[A,N]}\right] + \lambda\left[(1-\lambda)\widehat{P}_{[N,A]} + \lambda\widehat{P}_{[N,N]}\right], \quad \text{(B.16)}$$

with

$$\begin{aligned}
\widehat{P}_{[A,A]} &= s_1\widehat{P}_{A_1|[A,A]} + s_2\widehat{P}_{A_2|[A,A]} \\
\widehat{P}_{[A,N]} &= s_1\widehat{P}_{A_1|[A,N]} + s_2\widehat{P}_0 \\
\widehat{P}_{[N,A]} &= s_1\widehat{P}_0 + s_2\widehat{P}_{A_2|[N,A]} \\
\widehat{P}_{[N,N]} &= \widehat{P}_0
\end{aligned}$$

where s_1 is the (within-sector) market share of firm 1 and s_2 is the (within-sector) market share of firm 2; $\widehat{P}_{A_1|[A,A]}$ is the price change of firm 1 in the sector where both firms adjusted their prices, etc. It is worth noting that, since the firm does not observe its competitor's price in t when making its price decision, we have

$$\widehat{P}_{A_1|[A,A]} = \widehat{P}_{A_1|[A,N]} \equiv \widehat{P}_{A_1|[A,.]} \quad \text{and} \quad \widehat{P}_{A_2|[A,A]} = \widehat{P}_{A_2|[N,A]} \equiv \widehat{P}_{A_2|[.,A]}. \tag{B.17}$$

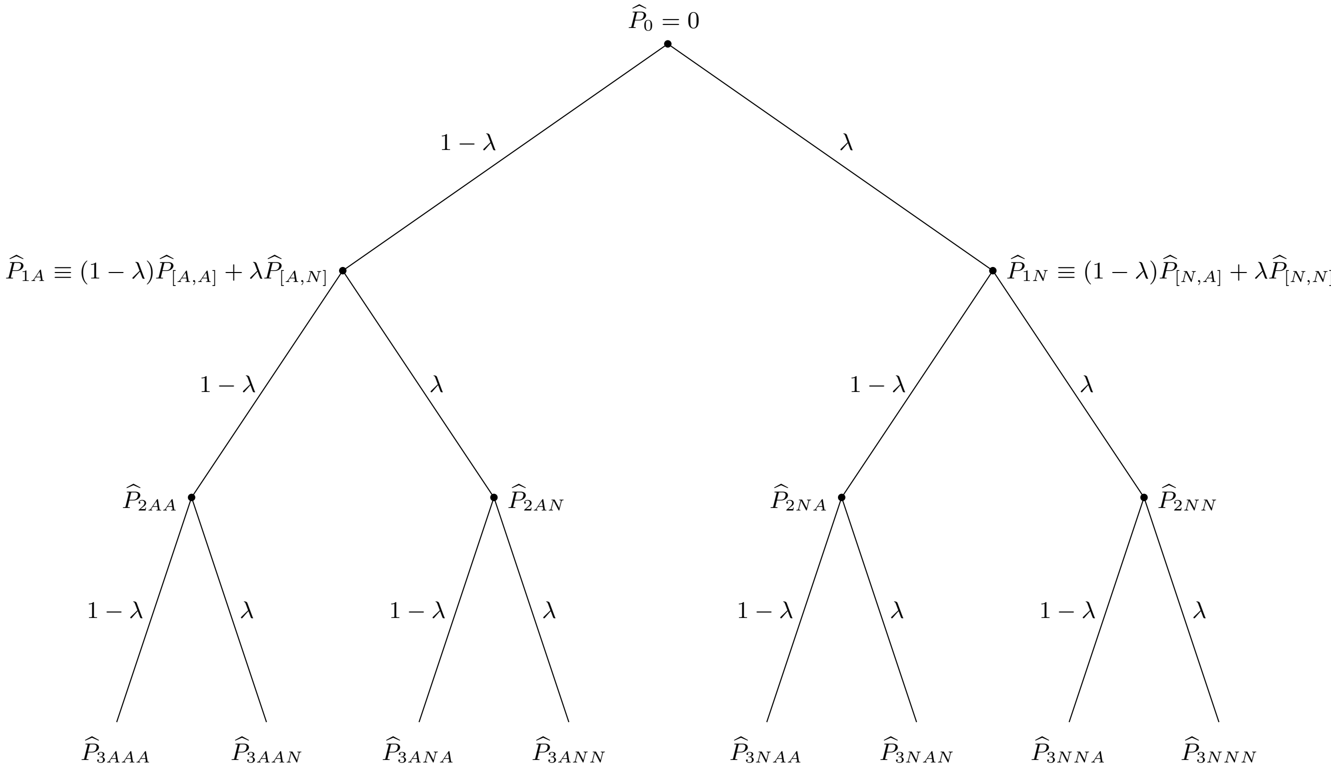


Figure B1: Illustrating the realization of sectoral and aggregate prices

Notes: This figure illustrates the discrete realization of the sectoral prices in an economy with *ex ante* symmetric firms and homogeneous duopoly sectors.

Define

$$\widehat{P}_{1,1} \equiv s_1 \left(\widehat{P}_{A_1|[A,A]} + \widehat{P}_{A_1|[A,N]} \right) + s_2 \left(\widehat{P}_{A_2|[A,A]} + \widehat{P}_{A_2|[N,A]} \right) = s_1 \widehat{P}_{A_1|[A,.]} + s_2 \widehat{P}_{A_2|[.,A]}.$$

We can rewrite the aggregate price as

$$\widehat{P}_1 = (1-\lambda)\widehat{P}_{1,1} + \lambda \widehat{P}_0. \tag{B.18}$$

Similarly, we have

$$\widehat{P}_2 = (1-\lambda)^2 \widehat{P}_{2AA} + (1-\lambda)\lambda \widehat{P}_{2AN} + \lambda(1-\lambda)\widehat{P}_{2NA} + \lambda^2 \widehat{P}_{2NN},$$

where

$$\begin{aligned}
\widehat{P}_{2AA} &= (1-\lambda)^2 \widehat{P}_{[AA,AA]} + (1-\lambda)\lambda \widehat{P}_{[AA,AN]} + \lambda(1-\lambda)\widehat{P}_{[AA,NA]} + \lambda^2 \widehat{P}_{[AA,NN]};\\
\widehat{P}_{2AN} &= (1-\lambda)^2 \widehat{P}_{[AN,AA]} + (1-\lambda)\lambda \widehat{P}_{[AN,AN]} + \lambda(1-\lambda)\widehat{P}_{[AN,NA]} + \lambda^2 \widehat{P}_{[AN,NN]};\\
\widehat{P}_{2NA} &= (1-\lambda)^2 \widehat{P}_{[NA,AA]} + (1-\lambda)\lambda \widehat{P}_{[NA,AN]} + \lambda(1-\lambda)\widehat{P}_{[NA,NA]} + \lambda^2 \widehat{P}_{[NA,NN]};\\
\widehat{P}_{2NN} &= (1-\lambda)^2 \widehat{P}_{[NN,AA]} + (1-\lambda)\lambda \widehat{P}_{[NN,AN]} + \lambda(1-\lambda)\widehat{P}_{[NN,NA]} + \lambda^2 \widehat{P}_{[NN,NN]}.
\end{aligned}$$

With some arrangements, it can be shown that

$$\widehat{P}_2 = (1-\lambda)\widehat{P}_{2,2} + \lambda \widehat{P}_1. \tag{B.19}$$

where

$$\begin{aligned}
\widehat{P}_{2,2} \equiv\ & s_1(1-\lambda)\left[(1-\lambda)\widehat{P}_{A_1|[AA,A.]} + \lambda \widehat{P}_{A_1|[AA,N.]}\right] + s_1\lambda\left[(1-\lambda)\widehat{P}_{A_1|[AN,A.]} + \lambda \widehat{P}_{A_1|[AN,N.]}\right]\\
&+ s_1\lambda\left[(1-\lambda)\widehat{P}_{A_1|[NA,A.]} + \lambda \widehat{P}_{A_1|[NA,N.]}\right]\\
&+ s_2(1-\lambda)\left[(1-\lambda)\widehat{P}_{A_2|[A.,AA]} + \lambda \widehat{P}_{A_2|[N.,AA]}\right] + s_2\lambda\left[(1-\lambda)\widehat{P}_{A_2|[A.,AN]} + \lambda \widehat{P}_{A_2|[N.,AN]}\right]\\
&+ s_2\lambda\left[(1-\lambda)\widehat{P}_{A_2|[A.,NA]} + \lambda \widehat{P}_{A_2|[N.,NA]}\right].
\end{aligned}$$

Further iteration provides expressions for $\widehat{P}_t$ when $t \geq 3$. The key takeaway is as follows: although the exact price dynamics are complex, the aggregate price dynamics can be succinctly represented in simple Calvo forms. As discussed in Section 2, three assumptions are crucial to arriving at this result: (1) The frequency of price adjustment is fixed and independent of the firms' pricing behavior; (2) There is a sufficiently large number of similar sectors, allowing the law of large numbers to be applicable; and (3) The shocks are small, ensuring that a first-order approximation remains accurate.

B.3 Simplified model with symmetric firms and homogeneous sectors

In this subsection, we discuss the aggregate price and output dynamics of our model using a simplified closed-economy model with symmetric firms and homogeneous sectors.

We start by aggregating the sectoral prices. From (14), we know the expected sectoral price follows

$$\mathbb{E}_t\widehat{P}_{jt+\tau} = (1-\lambda)\mathbb{E}_t\widehat{P}_{jt+\tau,t+\tau} + \lambda\mathbb{E}_t\widehat{P}_{jt+\tau-1}$$

As illustrated in Appendix B.2, the realization of the sectoral prices depends on the realization of the Calvo fairy and in general,

$$\widehat{P}_{jt+\tau} \neq (1-\lambda)\widehat{P}_{jt+\tau,t+\tau} + \lambda\widehat{P}_{jt+\tau-1}.$$

However, if there is a large number of *ex ante* identical sectors, the law of large number implies such that the aggregate price will still follow a Calvo process:

$$\widehat{P}_{t+\tau} = \frac{1}{J}\sum_j \widehat{P}_{jt+\tau} = \frac{1}{J}\sum_j (1-\lambda)\widehat{P}_{jt+\tau,t+\tau} + \frac{1}{J}\lambda\sum_j \widehat{P}_{jt+\tau-1} = (1-\lambda)\widehat{P}_{t+\tau,t+\tau} + \lambda\widehat{P}_{t+\tau-1},$$

where J is the number of *ex ante* homogeneous sectors.

Similarly, we can aggregate the sectoral Phillips curve (15) and re-express it as a second order difference equation of aggregate price levels:

$$\widehat{P}_t - \lambda\widehat{P}_{t-1} - \beta\lambda(\widehat{P}_{t+1} - \lambda\widehat{P}_t) = \frac{(1-\beta\lambda)(1-\lambda)}{(1+\varphi)}(\widehat{Q}_t^* + \varphi\widehat{P}_t). \tag{B.20}$$

Under a permanent monetary supply shock at t (i.e., $\widehat{M}_t = 1$), the desired producer price $\widehat{Q}_t^*$ moves one-to-one with the shock:

$$\widehat{Q}_t^* = \widehat{M}_t = 1. \tag{B.21}$$

Substituting (B.21) into (B.20), the aggregate price dynamics can be solved as

$$\widehat{P}_{t+\tau} - \widehat{P}_{t+\tau-1} = (1-\Lambda)\Lambda^\tau \quad \text{and} \quad \widehat{P}_{t+\tau} = 1 - \Lambda^{\tau+1}, \tag{B.22}$$

where

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

Since $P_t C_t = M_t$, the total cumulative change in consumption in response to a permanent monetary supply shock at t can be calculated as

$$\sum_{\tau=0}^{\infty} \widehat{C}_{t+\tau} = \sum_{\tau=0}^{\infty}(1-\widehat{P}_{t+\tau}) = \sum_{\tau=0}^{\infty}\Lambda^{\tau+1} = \frac{\Lambda}{1-\Lambda},$$

and the amplification relative to a standard Calvo model is given by

$$\frac{\Lambda(1-\lambda)}{\lambda(1-\Lambda)}. \tag{B.24}$$

Figure (B2) illustrates the effect of strategic complementarity on price and output dynamics in this homogeneous sector model.

Remarks. As $\varphi \to 0$, the dynamics of the model converges to a standard Calvo model with $\Lambda \to \lambda$. When the timing of price adjustment is perfectly synchronized that of the cost changes, the additional distribution layer of the model does not change the aggregate price and output dynamics when distributors are monopolistically competitive. To see this, note that, under the assumption of price and cost synchronization, the firm's expected future cost over the period in which its price is fixed is

$$\mathbb{E}_t Q_{t+\tau} = Q_t^* \tag{B.25}$$

and with monopolistically competitive distributors, the optimal reset price of the distributor (5) becomes

$$P_{t,t} = \frac{\mathbb{E}_t \sum_{\tau=0}^{\infty} (\beta\lambda)^\tau \theta c_{t+\tau,t}}{\mathbb{E}_t \sum_{\tau=0}^{\infty} (\beta\lambda)^\tau (\theta-1) c_{t+\tau,t}/Q_t^*} = \frac{\theta}{\theta-1} Q_t^* \tag{B.26}$$

which implies $\widehat{P}_{t,t} = \widehat{Q}_t^*$. In response to a permanent monetary policy shock, the price dynamics is exactly the same as in the standard Calvo model with only monopolistically competitive producers:

$$\widehat{P}_t = (1-\lambda)\widehat{Q}_t^* + \lambda\widehat{P}_{t-1} = (1-\lambda)\widehat{M}_t + \lambda\widehat{P}_{t-1}. \tag{B.27}$$

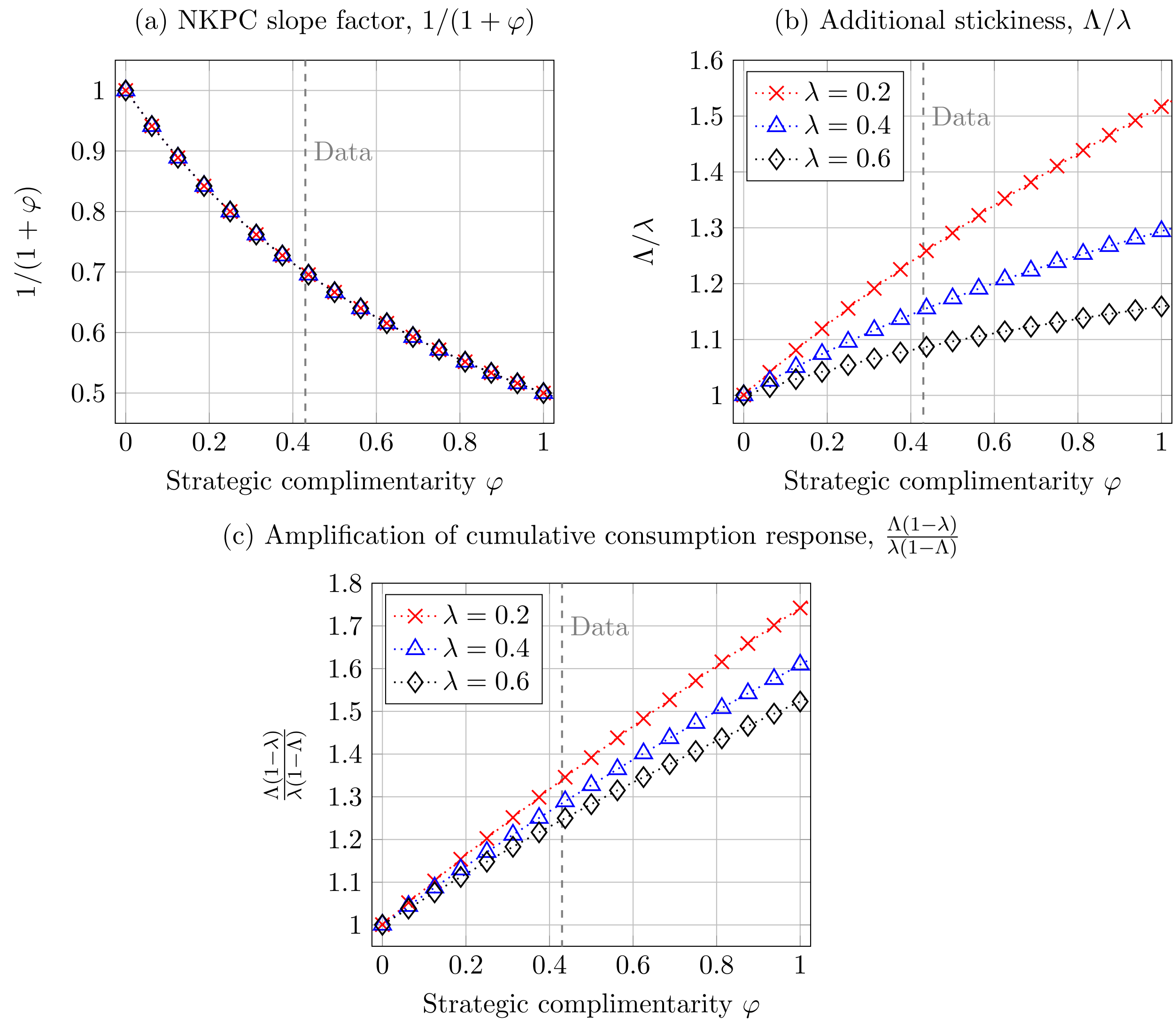


Figure B2: Effect of strategic complementarity on price and output dynamics in the homogeneous sector model (relative to monopolistic competition)

Similarly, under the assumption of synchronized cost and price adjustments, our full model—which features oligopolistic competitors alongside monopolistic competitive producers—yields the same aggregate dynamics as a model characterized by purely oligopolistic competition among producers without the inclusion of distributors. Therefore, the assumption of synchronization between cost and price adjustments not only mirrors the observed data characteristics of wholesalers but also facilitates the comparison of our theoretical results with recent models that feature oligopolistic competitors and no distributors (e.g., Mongey 2021, Wang and Werning 2022).

When the timing of price adjustment is perfectly synchronized that of the cost changes, the additional distribution layer of the model does not change the aggregate price and output dynamics. As we discussed in Appendix B.3, under the assumption of perfectly synchronized cost and price adjustments, our full model – which features oligopolistic competitors alongside monopolistic competitive producers – yields the same aggregate dynamics as a model characterized by purely oligopolistic competition among producers without the inclusion of distributors. Therefore, the assumption of synchronization between cost and price adjustments not only mirrors the observed data characteristics of wholesalers but also facilitates the comparison of our theoretical results with recent models that feature oligopolistic competitors and no distributors (e.g., Mongey 2021, Wang and Werning 2022).

B.3.1 Multi-country version

The takeaways of the above results carry over in a multi-country version of the model. The key difference in the multi-country version of the model is that a monetary policy shock or an exchange rate shock can no longer be considered as a "common" shock. For example, a monetary policy shock may not directly affect the costs of distributors that source their products from abroad, while exchange rate movements may not directly influence the costs of distributors sourcing domestically.

Our theoretical result on sectoral prices (B.2) suggests that the impact of an unexpected monetary policy shock (i.e., $\widehat{M}_t = 1$ and $\rho = 1$) depends on how it affects the average cost index of the industry $\widehat{Q}_{jt}^*$.

$$\mathbb{E}_t \widehat{P}_{jt+\tau} = \frac{\rho^{\tau+1} - \Lambda_{jt}^{\tau+1}}{\rho\left(1 - b_{jt}\right) + \lambda\left[\beta\rho(\lambda - \rho) - 1\right]} a_{jt}\widehat{Q}_{jt}^* \approx \left(1 - \Lambda^{\tau+1}\right)\widehat{Q}_{jt}^* \quad \forall \tau \geq 0. \tag{B.28}$$

In a simple setting where the change in marginal cost $\widehat{MC}_{ijt} = \widehat{M}_t = 1$ for domestically sourced firms and $\widehat{MC}_{ijt} = 0$ for foreign-sourced firms, the change in the average cost index of the industry $\widehat{Q}_{jt}^*$ depends on the total market share of domestically sourced firms s_{jD}:

$$\widehat{Q}_{jt}^* = s_{jD}\widehat{M}_t = s_{jD}. \tag{B.29}$$

The aggregate price dynamics can be expressed as a function of the mean market share of domestically sourced firms $s_D \equiv \sum_j \alpha_j s_{jD}$,

$$\widehat{P}_{t+\tau} = \left(1 - \Lambda^{\tau+1}\right) s_D \tag{B.30}$$

and when $\varphi \to 0$, we have $\widehat{P}_{t+\tau} = \left(1 - \lambda^{\tau+1}\right) s_D$ in a standard Calvo model. Therefore, although the magnitude of price change is attenuated by the fact that not all firms are directly affected by the monetary policy shock, the amplification effect of strategic complementarity relative to Calvo remains the same.

B.4 Model with heterogeneous sectors

Let $\alpha_z = \sum_{j\in z} \alpha_j$ denote the total market share of sectors with market structure z. Assuming a sufficiently large number of sectors in each structure type z, the price index for structure type z can be expressed as:

$$\widehat{P}_{zt+\tau} = \frac{1}{n_z}\sum_{j\in z}\widehat{P}_{jt+\tau} = \frac{1}{n_z}\sum_{j\in z}(1-\lambda_j)\widehat{P}_{jt+\tau,t+\tau} + \frac{1}{n_z}\sum_{j\in z}\lambda_j\widehat{P}_{jt+\tau-1} = (1-\lambda_z)\widehat{P}_{zt+\tau,t+\tau} + \lambda_z\widehat{P}_{zt+\tau-1}$$

where the law of large numbers is applied to derive the second equality. However, due to sectoral heterogeneity, the aggregate price no longer follows the standard Calvo form:

$$\widehat{P}_t = \sum_z \alpha_z \widehat{P}_{zt} = \sum_z \alpha_z (1-\lambda_z)\widehat{P}_{zt,t} + \sum_z \alpha_z \lambda_z \widehat{P}_{zt-1} \neq (1-\lambda)\widehat{P}_{t,t} + \lambda \widehat{P}_{t-1}, \tag{B.31}$$

where $\lambda \equiv \sum_z \alpha_z \lambda_z$. Note that the last inequality occurs because $\widehat{P}_{zt}$ is correlated with λ_z:

$$E[\lambda_z \widehat{P}_{zt}] = E[\lambda_z]E[\widehat{P}_{zt}] + Cov(\lambda_z, \widehat{P}_{zt})$$

where the expectation and covariance are taken over sectors z. To be more concrete, note that (B.31) can be rewritten as

$$\begin{aligned}
\widehat{P}_t =& (1-\lambda)\widehat{P}_{t,t} + \lambda \widehat{P}_{t-1} + Cov(\lambda_z, \widehat{P}_{zt-1}) - Cov(\lambda_z, \widehat{P}_{zt,t}) \\
=& (1-\lambda)\widehat{P}_{t,t} + \lambda \widehat{P}_{t-1} + Cov(\lambda_z, \widehat{P}_{zt-1}) - Cov\left[\lambda_z, \frac{1}{1-\lambda_z}\left(\widehat{P}_{zt} - \lambda_z \widehat{P}_{zt-1}\right)\right] \\
=& (1-\lambda)\widehat{P}_{t,t} + \lambda \widehat{P}_{t-1} - Cov\left[\lambda_z, \frac{1}{1-\lambda_z}\left(\widehat{P}_{zt} - \widehat{P}_{zt-1}\right)\right]
\end{aligned}$$

where $\lambda \equiv \sum_z \alpha_z \lambda_z$ and $Cov\left[\lambda_z, \frac{1}{1-\lambda_z}\left(\widehat{P}_{zt} - \widehat{P}_{zt-1}\right)\right]$ represents the additional price stickiness due to sectoral heterogeneity. Under a permanent monetary policy shock, we have

$$\widehat{P}_t = (1-\lambda)\widehat{P}_{t,t} + \lambda \widehat{P}_{t-1} - Cov\left[\lambda_z, \frac{1-\Lambda_z}{1-\lambda_z}\Lambda_z^\tau\right] \tag{B.32}$$

Alternatively, we can express this as a function of our derived closed-form sectoral solutions:

$$\widehat{P}_{t+\tau} \equiv \sum_z \alpha_z \widehat{P}_{zt+\tau} = \sum_z \alpha_z [1-(\Lambda_z)^{\tau+1}] = 1 - \Upsilon_\tau (\Lambda)^{\tau+1} = 1 - (\Lambda)^{\tau+1} + (1-\Upsilon_\tau)(\Lambda)^{\tau+1} \tag{B.33}$$

where $\Lambda \equiv \sum_z \alpha_z \Lambda_z$; and $\Upsilon_\tau \equiv \frac{\sum_z \alpha_z \Lambda_z^{\tau+1}}{\Lambda^{\tau+1}} > 1, ; \forall \tau > 0$ represents the further price stickiness due to sectoral heterogeneity. In the special case of monopolistic competition and a uniform distribution of price stickiness [i.e., $\Lambda_z = \lambda_z \sim \mathcal{U}(0, \varpi)$], the additional price stickiness can be expressed as $\Upsilon_\tau = \frac{2^{\tau+1}}{\tau+2} > 1, ; \forall \tau > 0$. Note that, as $\tau \to \infty$, $\Upsilon_\tau \to \infty$ but $(1-\Upsilon_\tau)\Lambda^{\tau+1} = \left(\frac{1}{\tau+2} - \frac{1}{2^{\tau+1}}\right)\varpi^{\tau+1} \to 0$. As illustrated in Figure B3, the amplification in aggregate price stickiness is time-specific and can be substantial even under monopolistic competition.

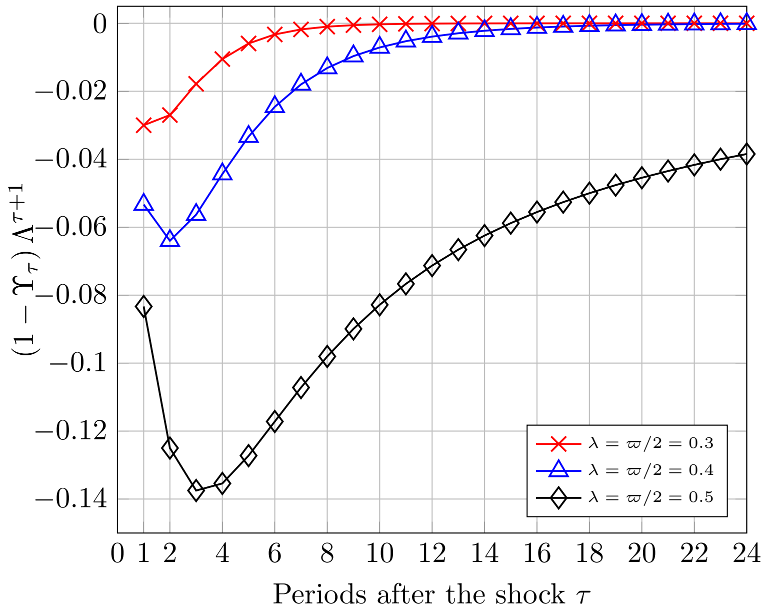


Figure B3: Effect of sectoral heterogeneity on aggregate price dynamics under standard Calvo

How does strategic complementarity affect this amplification effect? For clarity, we decompose this question into two parts: (a) the effect of strategic complementarity when there is no sectoral heterogeneity in market power $\varphi_z = \varphi$; and (b) the additional effect of heterogeneity in market power when $\varphi_z \neq \varphi$. Unfortunately, since $\Lambda(\lambda, \varphi)$ is a nonlinear function in price stickiness λ and market power φ, there is no simple analytical solution when $\varphi \neq 0$. We thus turn to numerically calculate Υ_τ.

We now proceed to match the heterogeneity in sectoral price stickiness and market power in our wholesale data. Specifically, we calculate the sectoral market power using the estimated pass-through to idiosyncratic cost shocks in each sector, i.e., $\varphi^{Est} = 1 - \frac{1}{\psi^{Est}}$. The following figures and tables show the counterpart statistics of those reported in 5, calculated based on the unweighted statistics.

(a) Price reduction due to sectoral heterogeneity　　(b) Output response

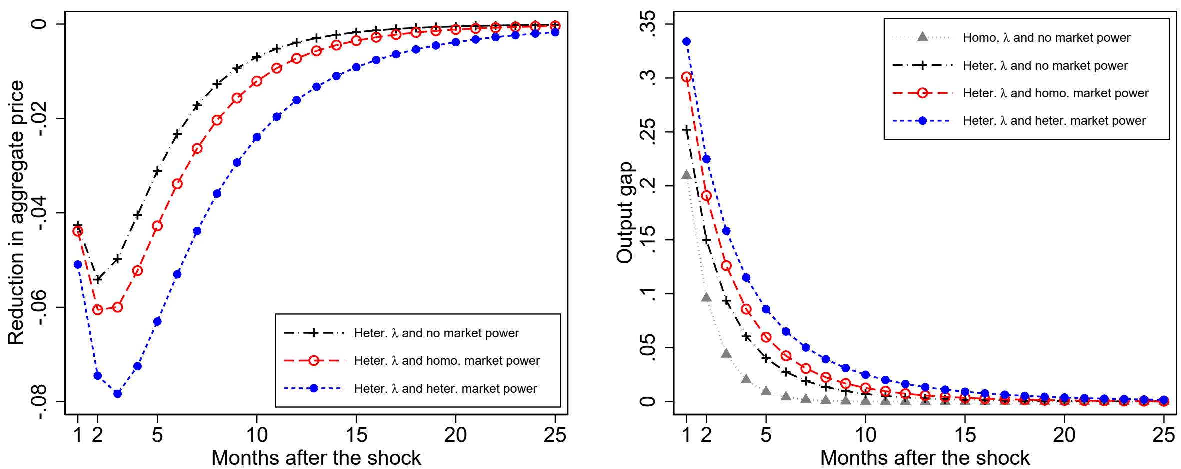


Figure B4: Amplification due to strategic complimentarity in multi-sector oligopoly model (moments matched to unweighted NAPCS7 data)

(a) Price reduction due to sectoral heterogeneity　　(b) Output response

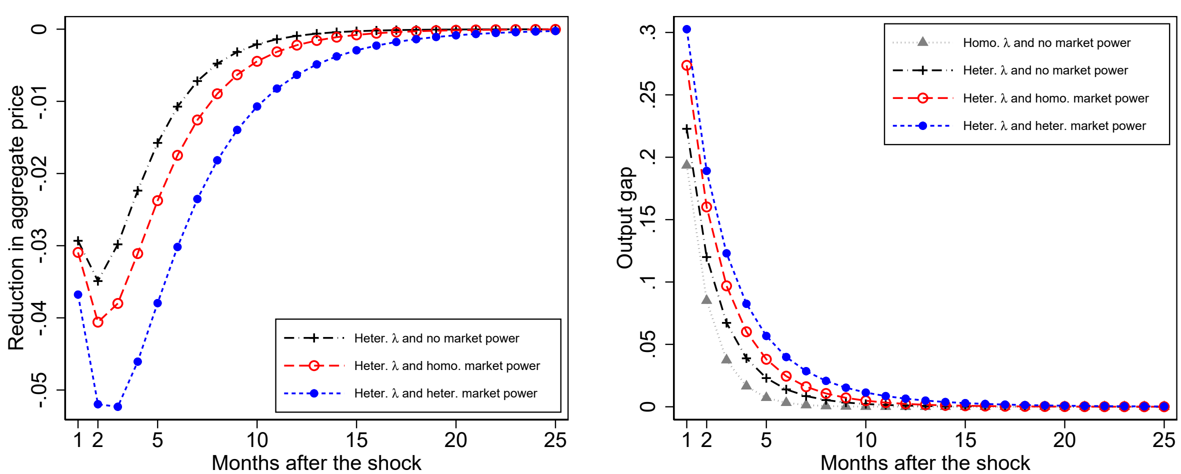


Figure B5: Amplification due to strategic complimentarity in multi-sector oligopoly model (moments matched to unweighted NAICS4 data)

Table B1: Statistics in multi-sector oligopoly model with sticky prices (based on unweighted moments)

Statistic	**Baseline**	**$\times$ Relative to Baseline**			
	MC(1) $(\lambda, \varphi = 0)$	OC(1) (λ, φ)	MC(J) $(\lambda_j, \varphi = 0)$	OC(J) (λ_j, φ)	OC(J) (λ_j, φ_j)
	(1)	(2)	(3)	(4)	(5)
(a) NAPCS7 products					
Output Response	0.84	1.27	1.37	1.71	2.11
Price Stickiness	0.46	1.13	1.17	1.29	1.40
Slope of NKPC	0.64	0.70	0.63	0.44	0.31
(b) NAICS4 sectors					
Output Response	0.79	1.28	1.21	1.52	1.81
Price Stickiness	0.44	1.14	1.11	1.24	1.34
Slope of NKPC	0.71	0.70	0.76	0.53	0.41

Notes: The table provides model statistics based on unweighted estimates from NAPCS7 products (panel a) and NAICS4 industries (panel b). The first row of each panel reports the cumulative response of aggregate output (in %) to an unanticipated permanent 1% increase in money supply The second row of each panel reports price stickiness λ 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 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 λ is set to the weighted mean price stickiness in the data and $\varphi = 0.43$. Column (3) reports statistics for a 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 the data.

B.5 Mapping to Amiti, Itskhoki and Konings (2019)

B.5.1 Background – the AIK framework

AIK provide a general *static* framework that decomposes a firm's price responses into two components: (1) the reaction to its own cost shocks, and (2) the reaction to its competitors' price adjustments. The core theoretical insights of this framework are encapsulated in their Propositions 1 and 2, which are succinctly restated below. These findings are applicable to all industries, and for the sake of brevity, we omit the industry-specific subscript j.

AIK Proposition 1 *For any given invertible demand system and competition structure, there exists a markup function $\mu_{it} = \mu_i\left(p_{it}, \boldsymbol{p}_{-it}; \boldsymbol{\xi}_t\right)$, such that the firm's static profit-maximizing price $\tilde{p}_{it}$ is the solution to the following fixed point equation, for any given price vector of the competitors $\boldsymbol{p}_{-it}$:*

$$\tilde{p}_{it} = mc_{it} + \mu_i\left(\tilde{p}_{it}, \boldsymbol{p}_{-it}; \boldsymbol{\xi}_t\right), \tag{B.34}$$

where $\boldsymbol{\xi}_t = (\xi_{1t}, ..., \xi_{Nt})$ is a vector of exogenous demand shifters and N is the number of firms in the industry.

Totally differentiating the best response condition (B.34) around some admissible point $(\tilde{p}_{it}, \boldsymbol{p}_{-it}; \boldsymbol{\xi}_t)$, e.g. any equilibrium point $(\boldsymbol{p}_t; \boldsymbol{\xi}_t)$, we obtain the following decomposition for the firm's log price differential:

$$\mathrm{d}p_{it} = \mathrm{d}mc_{it} + \frac{\partial \mu_i\left(\boldsymbol{p}_t; \boldsymbol{\xi}_t\right)}{\partial p_{it}}\,\mathrm{d}p_{it} + \sum_{k \neq i} \frac{\partial \mu_i\left(\boldsymbol{p}_t; \boldsymbol{\xi}_t\right)}{\partial p_{kt}}\,\mathrm{d}p_{kt} + \sum_{k=1}^{N} \frac{\partial \mu_i\left(\boldsymbol{p}_t; \boldsymbol{\xi}_t\right)}{\partial \xi_{kt}}\,\mathrm{d}\xi_{kt} \tag{B.35}$$

The markup function $\mu_i(\cdot)$ can be evaluated for an arbitrary price vector $\boldsymbol{p}_t = (p_{it}, \boldsymbol{p}_{-it})$, and therefore (B.35) characterizes all possible perturbations to the firm's price in response to shocks to its marginal cost $\mathrm{d}mc_{it}$, the prices of its competitors $\{\mathrm{d}p_{kt}\}_{k \neq i}$, and the demand shifters $\{\mathrm{d}\xi_{kt}\}_{k=1}^{N}$. Solving the fixed point for $\mathrm{d}p_{it}$ in (B.35) results in:

$$\mathrm{d}p_{it} = \frac{1}{1+\Gamma_{it}}\,\mathrm{d}mc_{it} + \frac{\Gamma_{-it}}{1+\Gamma_{it}}\,\mathrm{d}p_{-it} + \frac{1}{1+\Gamma_{it}}\varepsilon_{it}, \tag{B.36}$$

where

$$\Gamma_{it} \equiv -\frac{\partial \mu_i\left(\boldsymbol{p}_t; \boldsymbol{\xi}_t\right)}{\partial p_{it}} \quad \text{and} \quad \Gamma_{-it} \equiv \sum_{k \neq i} \frac{\partial \mu_i\left(\boldsymbol{p}_t; \boldsymbol{\xi}_t\right)}{\partial p_{kt}},$$

$$\mathrm{d}p_{-it} \equiv \sum_{k \neq i} \omega_{kt}\, \mathrm{d}p_{kt} \quad \text{with} \quad \omega_{it} \equiv \frac{\partial \mu_i\left(p_t; \xi_t\right)/\partial p_{kt}}{\sum_{k \neq i} \partial \mu_i\left(p_t; \xi_t\right)/\partial p_{kt}},$$

$$\varepsilon_{it} \equiv \sum_{k=1}^{N} \frac{\partial \mu_i\left(\boldsymbol{p}_t; \xi_t\right)}{\partial \xi_{kt}}\, \mathrm{d}\xi_{kt}.$$

AIK Proposition 2 *(i) If the log expenditure function p_t is a sufficient statistic for competitor prices, i.e. if the demand can be written as $q_{it} = q_i\left(p_{it}, p_t; \xi_t\right)$, then the weights in the competitor price index are proportional to the competitor revenue market shares s_{kt}, for $k \neq i$, and given by $\omega_{kt} \equiv s_{kt}/\left(1 - s_{kt}\right)$. Therefore, the index of competitor price changes simplifies to:*

$$\mathrm{d}p_{-it} \equiv \sum_{k \neq i} \frac{s_{kt}}{1 - s_{kt}}\, \mathrm{d}p_{kt}. \tag{B.37}$$

(ii) Under the stronger assumption that the perceived demand elasticity is a function of the price of the firm relative to the industry expenditure function, $\sigma_{it} = \sigma_i\left(p_{it} - p_t; \xi_t\right)$, the following two markup elasticities are equal:

$$\Gamma_{-it} \equiv \Gamma_{it}. \tag{B.38}$$

A key implication of Proposition 2 is that, under the relatively mild conditions imposed by AIK, the pass-through to the firm's own cost shock and the firm's competitors' price changes (i.e., the first two coefficients in the price decomposition (B.36)) should sum to one:

$$\frac{1}{1 + \Gamma_{it}} + \frac{\Gamma_{-it}}{1 + \Gamma_{it}} = 1. \tag{B.39}$$

AIK empirically test (B.39) with Belgium data and find strong empirical support of this theoretical relationship.

Remarks. It is worth noting that, the decomposition (B.36) cannot be applied directly in empirical estimations. This is because, in an oligopolistic competition model, the firms' prices are jointly determined. Since a firm's competitors' price changes $\mathrm{d}p_{-it}$ are endogenous and depend on the firm's price change $\mathrm{d}p_{it}$, directly estimating (B.36) can result in substantial bias. To address this concern, AIK use proxies of the competitors' cost changes as instruments for the competitors' price changes.

B.5.2 Response to cost shocks under the AIK framework

The fundamental reason for the need of an instrument is that the decomposition (B.36) is an "unsolved" version of the equilibrium conditions as it writes the firm's price change as a function of the endogenous variable $\mathrm{d}p_{-it}$. In what follows, we derive the corresponding "solved" version of the decomposition in terms of exogenous shocks.

First, note that we can rewrite the price change decomposition (B.36) as follows

$$
\begin{aligned}
& \mathrm{d}p_{it} = \frac{1}{1+\Gamma_{it}}\ \mathrm{d}mc_{it} + \frac{\Gamma_{-it}}{1+\Gamma_{it}}\ \mathrm{d}p_{-it} + \frac{1}{1+\Gamma_{it}}\varepsilon_{it} \\
\Leftrightarrow\quad & \mathrm{d}p_{it} = \frac{1}{1+\Gamma_{it}}\ \mathrm{d}mc_{it} + \frac{\Gamma_{it}}{1+\Gamma_{it}}\ \mathrm{d}p_{-it} + \frac{1}{1+\Gamma_{it}}\varepsilon_{it} && \text{(B.40)} \\
\Leftrightarrow\quad & (1-s_{it})(1+\Gamma_{it})\mathrm{d}p_{it} = (1-S_{it})\ \mathrm{d}mc_{it} + \Gamma_{it}\sum_{k\neq i} s_{kt}\ \mathrm{d}p_{kt} + (1-s_{it})\varepsilon_{it} && \text{(B.41)} \\
\Leftrightarrow\quad & \mathrm{d}p_{it} = \frac{1-s_{it}}{1-S_{it}+\Gamma_{it}}\ \mathrm{d}mc_{it} + \frac{\Gamma_{it}}{1-s_{it}+\Gamma_{it}}\ \mathrm{d}p_t + \frac{1-s_{it}}{1-s_{it}+\Gamma_{it}}\varepsilon_{it} && \text{(B.42)}
\end{aligned}
$$

where (B.40) uses relationship (B.38); (B.41) uses relationship (B.37); and (B.42) uses the definition of the sectoral price index such that $\mathrm{d}p_t = \sum_k s_{kt}\ \mathrm{d}p_{kt}$. Note that the only endogenous variable in (B.42) is the changes in the sectoral price index $\mathrm{d}p_t$.

Next, to solve for $\mathrm{d}p_t$, we aggregate expression (B.42) across all firms:

$$
\sum_i s_{it}\mathrm{d}p_{it} = \sum_i \frac{s_{it}(1-s_{it})}{1-s_{it}+\Gamma_{it}}\ \mathrm{d}mc_{it} + \sum_i \frac{\Gamma_{it}s_{it}}{1-s_{it}+\Gamma_{it}}\ \mathrm{d}p_t + \sum_i \frac{s_{it}(1-s_{it})}{1-s_{it}+\Gamma_{it}}\varepsilon_{it} \tag{B.43}
$$

Rearranging (B.43), we can express the changes in the sectoral price index $\mathrm{d}p_t$ as a function of exogenous marginal cost and demand shocks:

$$
\mathrm{d}p_t = \sum_i \widetilde{\varphi}_{it}\ \mathrm{d}mc_{it} + \sum_i \widetilde{\varphi}_{it}\varepsilon_{it} \tag{B.44}
$$

with

$$\varphi_{it} \equiv \frac{1 - s_{it}}{1 - s_{it} + \Gamma_{it}} \quad \text{and} \quad \widetilde{\varphi}_{it} \equiv \frac{\varphi_{it} s_{it}}{\sum_k \varphi_{kt} s_{kt}},$$

where, as we show below in (B.47), $\varphi_{it} > 0$ is the firm's response to idiosyncratic shocks and $\lambda_{it} > 0$ is the implicit importance weight of the idiosyncratic shocks with $\sum_i \widetilde{\varphi}_{it} = 1$. When $\varepsilon_{it} = 0 \ \forall i$, expression (B.44) is equivalent to the expression in Proposition 3 of AIK.

Finally, substitute (B.44) into (B.42) and we get the *solved* version of the price change decomposition:

$$\mathrm{d}p_{it} = \underbrace{[\varphi_{it} + (1 - \varphi_{it})\widetilde{\varphi}_{it}]\,[\,\mathrm{d}mc_{it} + \varepsilon_{it}]}_{\text{pass-through to } \textit{own} \text{ cost and demand shocks}} + \underbrace{(1 - \varphi_{it})\left[\sum_{k \neq i} \widetilde{\varphi}_{kt}\ \mathrm{d}mc_{kt} + \sum_{k \neq i} \widetilde{\varphi}_{kt}\varepsilon_{kt}\right]}_{\text{pass-through to } \textit{competitors'} \text{ cost and demand shocks}} \tag{B.45}$$

It can be shown that, under a common cost or demand shock, the price pass-through of *each firm* is 100% as

$$[\varphi_{it} + (1 - \varphi_{it})\widetilde{\varphi}_{it}] + (1 - \varphi_{it}) \sum_{k \neq i} \widetilde{\varphi}_{kt} = 1.$$

Defining the common cost and demand shocks as

$$\mathrm{d}mc_t \equiv \sum_i \widetilde{\varphi}_{it}\ \mathrm{d}mc_{it} \quad \text{and} \quad \varepsilon_t \equiv \sum_i \widetilde{\varphi}_{it}\varepsilon_{it}, \tag{B.46}$$

the price change decomposition can be re-expressed in terms of common versus idiosyncratic shocks:

$$\mathrm{d}p_{it} = \varphi_{it}(\mathrm{d}mc_{it} - \mathrm{d}mc_t) + \ \mathrm{d}mc_t + \varphi_{it}(\varepsilon_{it} - \varepsilon_t) + \varepsilon_t. \tag{B.47}$$

The first term of (B.47) shows that, in this static framework, the pass-through rate to a common cost shock is always equal to 100%. The second term shows that the pass-through rate to an idiosyncratic cost shock ($\mathrm{d}mc_{it} - \mathrm{d}mc_t$) is well defined and given by φ_{it}. Under the structural assumptions of Atkeson and Burstein (2008), φ_{it} is a strictly *decreasing* function of market share s_{it}. Intuitively, this is because large firms with market power absorb part of their cost shocks into markups, while small firms do not adjust markups and thus fully pass-through any idiosyncratic cost shock. It is worth noting that, different from Γ_{it} which is hump-shaped in market share, φ_{it} is a strictly decreasing function of market share (see figure B6).[27]

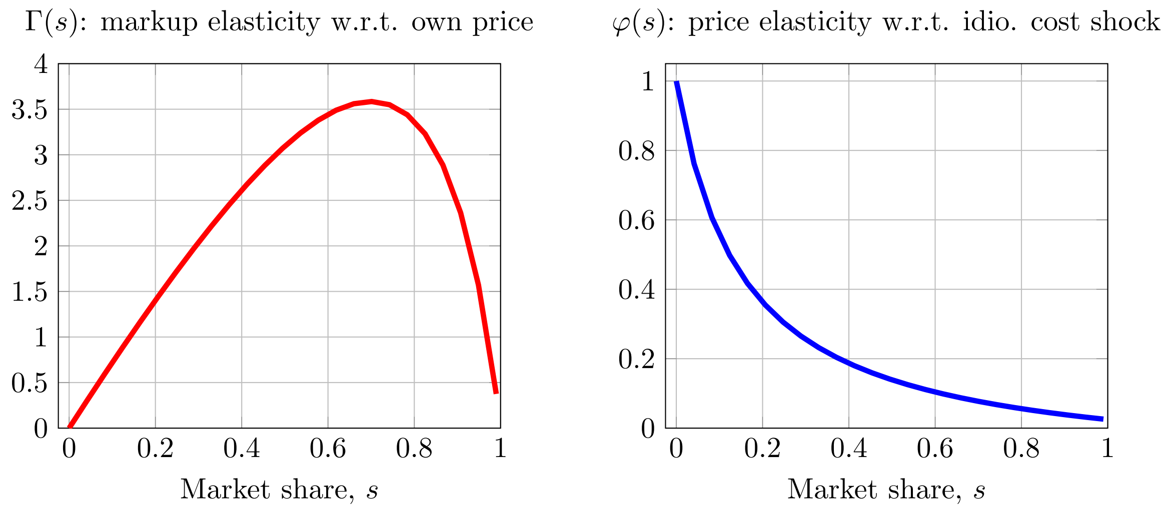


Figure B6: Market share and key elasticities

Note: the two figures plot $\Gamma(s)$ and $\varphi(s)$ under the nested-CES demand preference of Atkeson and Burstein (2008), where the within-industry elasticity of substitution is set to 10 and the cross-industry elasticity of substitution is set to 1.2.

Unlike AIK's original decomposition (B.36), our decomposition (B.47) involves no endogenous variable and thus does not need an instrument. Assuming the demand shocks are exogenous and i.i.d. (as in AIK), equation (B.47) can be directly estimated using OLS provided that a good measure of the common cost shock $\mathrm{d}mc_t$ can be constructed.

B.5.3 Cournot vs Bertrand Competition

Consistent with the literature, we have assumed Cournot competition in our baseline model as it tends to better match the relationship between the estimated pass-through rates and empirical market share distributions (see Atkeson and Burstein 2008 and Amiti, Itskhoki and Konings 2019). Figure B7 contrasts the sufficient statistic $\varphi(\theta, s)$ in our model under Bertrand and Cournot compe-

[27] From the definition of $\varphi_{it} = 1/[1 + \Gamma(s_{it})/(1 - s_{it})]$, we see there are two market share effects as a firm becomes larger: (i) a direct market share effect captured by $(1 - s_{it})$ and (ii) an indirect effect through markup adjustment captured by $\Gamma(s_{it})$. The two effects go in the same direction and reduce price pass-through to an idiosyncratic shock until the firm becomes extremely large (e.g., when it accounts for over 80% of the market share). For those extremely large firms, the two effects go in opposite directions: as a firm becomes extremely large it cares less about the cost shocks of other smaller firms (captured by i) and makes smaller markup adjustments (captured by ii). It turns out that the direct effect (i) dominates as a firm becomes extremely large and therefore the price pass-through to an idiosyncratic shock is strictly decreasing in the firm's market share.

tition. We observe that Cournot competition results in larger strategic complementarity (measured by φ) for a given market share, s, and is more sensitive to the assumed elasticity of substitution, θ. The first two panels of Figure B8 illustrate the theoretical pass-through rate to idiosyncratic cost shocks, $1/(1+\varphi)$, at different market shares, s, and elasticity of substitution, θ, under Cournot competition. Panel (c) of Figure B8 provides all the market share and elasticity combinations that yield an empirical coefficient of 0.7.

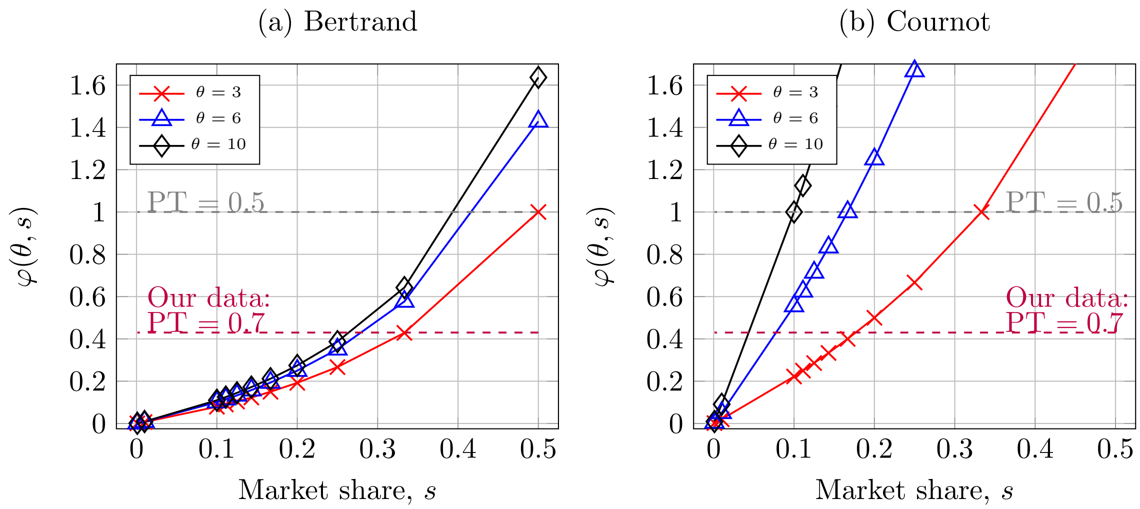


Figure B7: Sufficient statistic $\varphi(\theta, s)$ under Bertrand vs Cournot competition

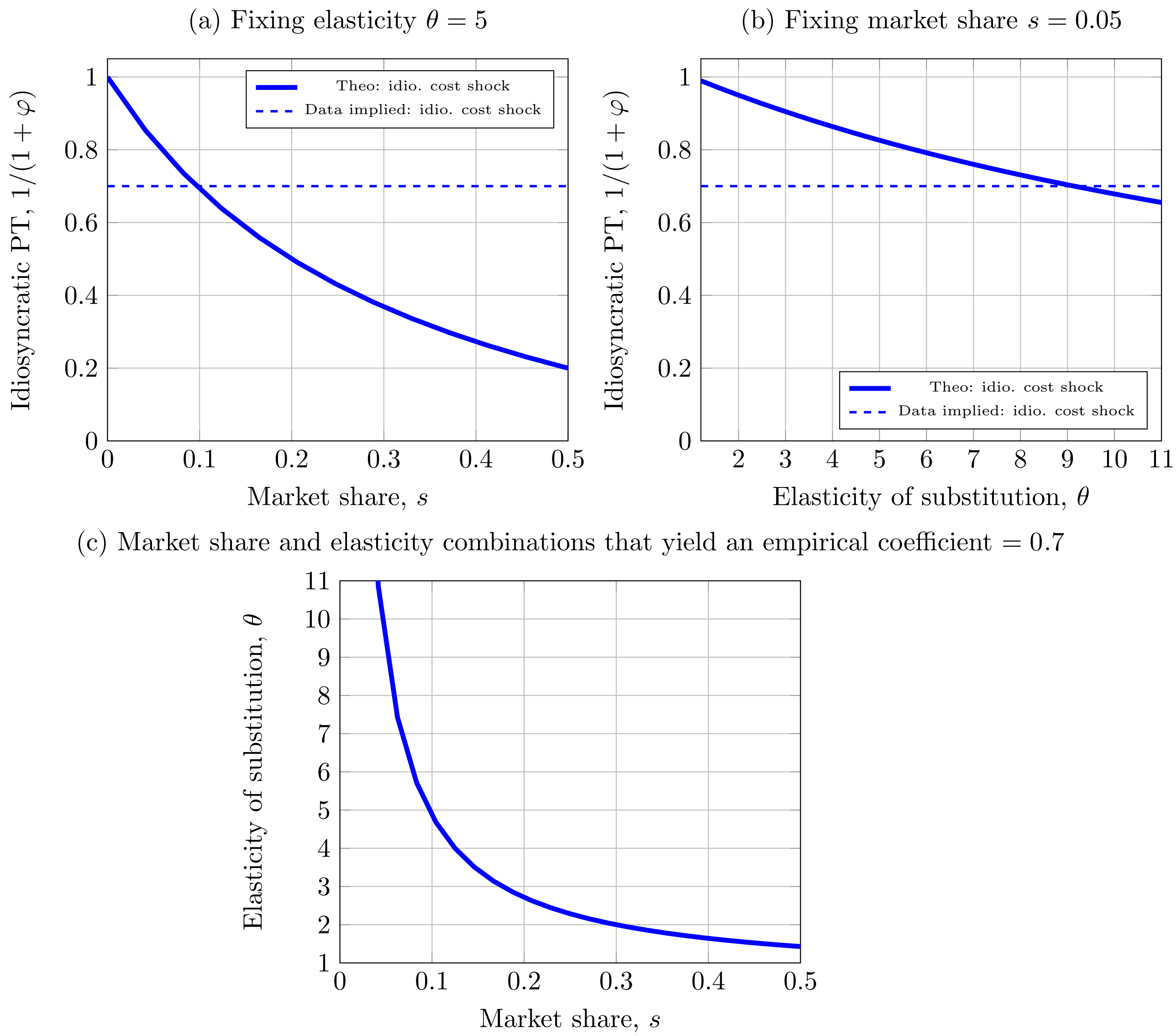


Figure B8: Theoretical responses to idio. cost shocks $1/(1+\varphi)$ under Cournot competition