Does competition increase pass-through?

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Abstract

How does market power affect the rate of pass-through from marginal cost to the market price? A standard intuition is that more competition makes prices more "cost-reflective" and thus raises cost pass-through. This paper shows that this intuition is sensitive to the common assumption in the literature that firms' marginal costs are constant. If firms have even modestly increasing marginal costs, more intense competition can reduce pass-through. These results apply to the "normal" case where pass-through is less than 100%. They have implications for antitrust policy, environmental regulation, and incidence analysis.

Keywords: Cost pass-through, imperfect competition, perfect competition, price theory, production technology
JEL codes: D24 (production), D40 (market structure and pricing)

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1 Introduction

In recent years, the literature has seen a surge of interest in using cost pass-through as a tool for policy and welfare analysis across fields including industrial organization (Weyl & Fabinger 2013), environmental economics (Fabra & Reguant 2014), international trade (Mrázová & Neary 2017), and development economics (Atkin & Donaldson 2015). At the same time, widespread concerns have emerged about the rising market power of firms—potentially as the result of globalization, soft antitrust enforcement, increasing ownership concentration, among other factors (Shapiro 2019; Syverson 2019).

This paper addresses a basic question that links these two themes: how does market power affect pass-through? A common intuition is that firms with market power have an incentive to "absorb" part of a cost increase whereas, under perfect competition, price equals marginal cost ($P = MC$) so the rate of pass-through of a market-wide increase in marginal cost (dP/dMC) is 100%. This suggests that more intense competition leads to stronger pass-through. Perhaps most prominently, this intuition holds in a textbook linear Cournot model, with a 50% pass-through rate under monopoly which rises up to 100% as the number of firms grows large.

Yet this intuition and existing theory literature on pass-through under imperfect competition (e.g., Bulow & Pfleiderer 1983; Kimmel 1992; Anderson & Renault 2003; Weyl & Fabinger 2013; Mrázová & Neary 2017) maintain the assumption that firms have constant marginal costs. On one hand, this is a substantive economic assumption which may be appropriate for some markets but less so for others. On the other hand, it obscures the comparison with the benchmark of perfect competition—precisely because it restricts competitive pass-through to a "knife-edge" rate of 100%.

This paper generalizes earlier results from the pass-through literature and highlights their sensitivity to the assumption of constant marginal cost. The model has two key features. First, to facilitate the comparison with perfect competition, the industry sells a homogenous product and the setup nests monopoly, oligopoly and perfect competition as special cases. Second, firms have convex cost functions, which can be justified purely on technological grounds or by invoking the frictions that arise from principal-agent problems within the firm (Hart 1995).

The main point is that, if firms have even modestly increasing marginal costs, the standard intuition is overturned—and more intense competition actually *reduces* pass-through. A less flexible production technology, with more steeply increasing marginal cost, always leads to lower pass-through. This holds in a textbook model of perfect competition and extends to imperfect competition. However, the effect also tends to be pronounced for a more competitive market because it has higher industry output. This helps explains why, in markets with a fairly inflexible production technology, more competition can be associated with less pass-through. Importantly, this finding applies

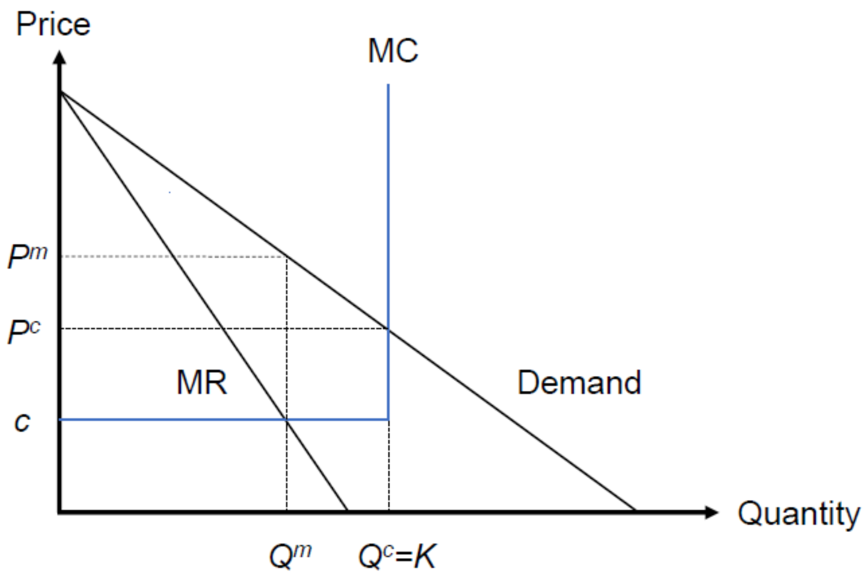

Figure 1: A case in which monopoly cost pass-through exceeds competitive pass-through

to the "normal" case where pass-through is less than 100%.

The quickest way to see the result is to look at Figure 1. Market demand (P) is linear and the industry marginal revenue (MR) curve is twice as steep. The marginal cost of production (MC) is a constant c up to the industry's K units of installed capacity. A monopoly optimally produces $Q^m < K$ units at marginal cost c, leading to the textbook result of a cost pass-through rate of 50% (=[slope of P]/[slope of MR]). A competitive industry, by contrast, produces at capacity, $Q^c = K$, and therefore has a pass-through rate of zero.[1] So competition reduces cost pass-through. While very simple, this point appears to be novel to the literature on price theory.

The analysis in this paper presents more general versions of this point using two approaches. One approach extends the argument in Figure 1 to general non-linear demand, non-linear costs, and market structures. It derives conditions on primitives to characterize when more intense competition reduces equilibrium pass-through. Sufficient conditions are that (i) the market demand curve is concave, linear or not too convex, (ii) demand is weakly more convex at higher prices, and (iii) cost convexity is pronounced enough.

The other approach compares in the cross-section two markets which may have different underlying demand and/or cost functions. For a like-for-like comparison, suppose that any such differences are controlled for—specifically, in the (equilibrium values of the) price elasticity of demand, the curvature of demand, and the curvature of costs. Under plausible conditions, the more competitive market again always has lower pass-through if cost convexity is sufficiently pronounced. For example, this always occurs if demand is convex and firms' cost functions are at least as convex as a quadratic.

[1]A competitive industry here produces at capacity both before and after incurring a small marginal cost increase—so the market price also remains unchanged.

The interplay between pass-through and market power plays an important role across several policy domains. The pass-through of fuel costs to retail electricity prices and gasoline prices regularly attracts the attention of competition policymakers (Federal Trade Commission 2011; Competition and Markets Authority 2015).[2] A related antitrust issue is the "passing-on defense" by which the damages from an upstream cartel may be limited by downstream firms passing the overcharge onto their own customers (Verboven & Van Dijk 2009). Another application is market-based regulation towards climate change for which the pass-through of a carbon price imposed on an energy-intensive industry such as cement, electricity or steel plays a central role for policy design and effectiveness (Fabra & Reguant 2014; Miller, Osborne & Sheu 2017).

This paper follows the literature on industrial organization and environmental economics in focusing on the pass-through *rate* dP/dMC rather than the pass-through *elasticity* $d\ln P/d\ln MC$ which is more widely used in macroeconomics and international trade. The condition for market power to raise a pass-through elasticity will be tighter as there is also a higher price-cost mark-up P/MC. However, it is immediate from Figure 1 that the main point can also apply to a pass-through elasticity—which is positive for monopoly but zero under perfect competition.

Section 2 sets up the model, and Section 3 presents a unifying equilibrium result on cost pass-through that applies under both perfect and imperfect competition. Section 4 presents conditions under which more competition leads to weaker cost pass-through. Section 5 discusses the empirical implications of the theory in light of recent econometric work on cost pass-through. Section 6 concludes.

2 The model

Consider a simple model of imperfect competition between n symmetric firms that nests perfect competition and monopoly as special cases.

The inverse demand curve is $p(X)$, where p is the market price, X is industry output and $p'(\cdot) < 0$. Let $\varepsilon^D \equiv -p(X)/Xp'(X) > 0$ be the price elasticity of demand and let $\xi^D \equiv -Xp''(X)/p'(X)$ be a measure of demand curvature. Demand is concave if $\xi^D \leq 0$ and convex otherwise; it is log-concave (i.e., the log of direct demand $\ln D(p)$ is concave in p) if $\xi^D \leq 1$ and log-convex otherwise. Demand curvature can also be expressed as $\xi^D = 1 + (1-\psi^D)/\varepsilon^D$, where $\psi^D \equiv [d\varepsilon^D(p)/dp]/[\varepsilon^D(p)/p]$ is the superelasticity of demand, i.e., the elasticity of the elasticity (Kimball 1995). So demand is log-concave $\xi^D \leq 1$ if and only if it is unit-superelastic $\psi^D \geq 1$.[3]

[2] The present paper does not address issues related to the speed and frequency of price adjustments in response to cost shocks.

[3] Mrázová & Neary (2017) use the term "subconvex" for demands with positive superelasticity $\psi^D \geq 0$; this condition is sometimes also referred to as Marshall's "second law of demand."

Firm i has a cost function $\widehat{C}(x_i) \equiv [C(x_i)+\tau x_i]$ where x_i is its output (so $X \equiv \sum_i x_i$), τ is a cost shifter, and which satisfies $C'(\cdot) > 0, C''(\cdot) \geq 0$ (where $\widehat{C}''(x_i) = C''(x_i)$). Let $\eta_i^S \equiv x_i\widehat{C}''(x_i)/\widehat{C}'(x_i) \geq 0$ be the elasticity of i's marginal cost which, given symmetry, will be identical across firms with $\eta_i^S = \eta^S$. This can be seen as a measure of the "inflexibility" of the production technology.[4]

Remark 1. The model defines the elasticity of firm i's marginal cost $\widehat{C}'(x_i)$ *including* the cost shifter τ. Many papers on pass-through focus on the case in which the initial value of the cost shifter is zero, $\tau = 0$. Then marginal cost is (locally) identical including and excluding the cost shifter $\widehat{C}'(x_i) = C'(x_i)$, and so the cost elasticity $\eta_i^S = x_iC''(x_i)/C'(x_i)$ can equivalently be written without the cost shifter.[5] This paper does not restrict attention to $\tau = 0$, though its findings also apply to this case.

Firm i's profits are given by $\Pi_i = p(X)x_i - C(x_i) - \tau x_i$. Each firm chooses its output x_i in a generalized version of quantity competition. The industry's conduct parameter $\theta \in [0, 1]$ serves as a summary statistic of the intensity of competition. Formally, firms' equilibrium outputs $(x_i^*)_{i=1...n}$ satisfy:

$$x_i^* = \arg\max_{x_i \geq 0} \{p(\theta(x_i - x_i^*) + X^*)x_i - C(x_i) - \tau x_i\}. \tag{1}$$

Firm i, in deviating its output by $(x_i - x_i^*)$, conjectures that industry output will change by $\theta(x_i - x_i^*)$ as a result. In this "conduct equilibrium", lower values of θ correspond to more intense competition. This setup can be viewed as a reduced-form representation of a dynamic game (Cabral 1995). The Cournot-Nash equilibrium, where each firm takes its rivals' output as given, occurs where $\theta = 1$, and perfect competition with price-taking firms where $\theta = 0$.

Two further conditions will ensure a well-behaved interior equilibrium. First, a sufficient condition for an interior equilibrium is that $p(0) > \widehat{C}(0) = C'(0) + \tau$. Second, the condition $\xi^D < 2$, such that the industry's marginal revenue is downward-sloping, will ensure a well-behaved equilibrium, regardless of the intensity of competition.

The first-order condition for firm i is:

$$p(X) + \theta x_i p'(X) - \widehat{C}'(x_i) = 0 \text{ at } x_i = x_i^*. \tag{2}$$

This says that a generalized version of firm i's marginal revenue equals its marginal cost.[6]

[4] The symmetry assumption is made for simplicity and is not crucial for the results; for example, the analysis would extend to marginal-cost asymmetry of the form $C'(x_i) = c_i + \mu(x_i)$ (given a fixed number of firms n). Similarly, the analysis would extend to a simple model of vertical product differentiation in which firm i's price $p_i(X) = \sigma_i + p(X)$ reflects its product quality σ_i—even if this would complicate the comparison with the benchmark of perfect competition.

[5] More generally, they are related according to $\eta_i^S = [x_iC''(x_i)/C'(x_i)] / [1 + \tau/C'(x_i)]$.

[6] The second-order condition for firm i is: $(1+\theta)p'(X)+\theta p''(X)x_i - C''(x_i) < 0 \Leftrightarrow (1+\theta) - (x_i/X)\theta\xi + C''(x_i)/[-p'(X)] > 0$, which is always satisfied given the assumptions $\theta \in [0, 1]$, $\xi^D < 2$, $C''(x_i) \geq 0$.

In symmetric equilibrium, $X^* = nx^*$, and so the first-order condition becomes:

$$p(nx^*) + \theta x^* p'(nx^*) - \widehat{C}'(x^*) = 0. \tag{3}$$

Let $\widehat{\theta}^S \equiv (\theta/n)$ be an index of market power which is higher with a larger conduct parameter and/or fewer firms. Writing $p(\tau, \widehat{\theta}^S)$ for the equilibrium price, the role of this index is made precise as follows:

Lemma 1 *The equilibrium elasticity-adjusted Lerner index* $L \equiv \varepsilon^D[p(X) - \widehat{C}'(x)]/p(X) = \widehat{\theta}^S \in [0, 1]$*, where the equilibrium market price* $p(\tau, \widehat{\theta}^S)$ *rises with market power* $\widehat{\theta}^S$*.*

The setup facilitates comparative statics on competition via changes in $\widehat{\theta}^S$ (where both θ and n are exogenous). As expected, less intense competition leads to a higher market price (and lower industry output). Note also that, at equilibrium, the price elasticity of demand cannot be too low, with $\varepsilon^D > \widehat{\theta}^S$ (and so $\varepsilon^D > 1$ for monopoly).

3 Equilibrium cost pass-through

The first step in the main analysis is to derive an expression for the rate of cost pass-through: the change in the equilibrium market price arising from a small market-wide rise in marginal cost, $\rho \equiv dp(\tau, \widehat{\theta}^S)/d\tau$.

Lemma 2 *The equilibrium rate of cost pass-through equals:*

$$\rho(\varepsilon^D, \xi^D, \eta^S, \widehat{\theta}^S) = \frac{1}{\left[1 + (\varepsilon^D - \widehat{\theta}^S)\eta^S + \widehat{\theta}^S(1 - \xi^D)\right]} > 0.$$

Lemma 2 nests various results from prior literature.[7] First, under perfect competition ($\widehat{\theta}^S = 0$), the first-order condition (2) defines firm i's supply curve; letting $\varepsilon_i^S \equiv px_i'(p)/x_i(p) > 0$ be firm i's price elasticity of supply, at symmetric equilibrium, $\varepsilon_i^S = \varepsilon^S$ and $\eta^S = 1/\varepsilon^S$. This leads to the textbook result that competitive pass-through $\rho = \varepsilon^S/(\varepsilon^S + \varepsilon^D)$ is driven by the ratio of demand and supply elasticities—and is never greater than 100%.

Second, under monopoly (Bulow & Pfleiderer 1983) or monopolistic competition (Mrázová & Neary 2017) with constant marginal cost ($n = 1$, $\theta = 1$, $\eta^S = 0$), pass-through $\rho = 1/(2 - \xi^D)$ is determined solely by demand curvature ξ^D—with no distinct role for the price elasticity of demand ε^D.

[7] To the best of my knowledge, Lemma 2's expression for cost pass-through is a new result, as it allows for both convex costs, $\eta^S > 0$, and market power, $\widehat{\theta}^S > 0$.

Third, under Cournot-Nash competition (Kimmel 1992) with constant marginal cost ($\theta = 1$, $\eta^S = 0$), pass-through $\rho = 1/[1+\widehat{\theta}^S(1-\xi^D)]$ is additionally determined by market structure—as then given by the competition index $\widehat{\theta}^S \equiv (1/n)$.

Lemma 2 shows that, more generally, pass-through is determined by four factors: the price elasticity of demand ε^D, demand curvature ξ^D, the elasticity of marginal cost η^S, and the intensity of competition $\widehat{\theta}^S$. The role of the demand elasticity ε^D is predicated on the presence of the cost elasticity, $\eta^S > 0$, which is often assumed away in prior literature.

It is easy to see that, all else equal, pass-through is always lower for a less flexible production technology, that is, $\partial\rho/\partial\eta^S < 0$. In this sense, a basic insight from perfect competition extends to settings with market power. In the limit, pass-through tends to zero, $\rho \to 0$, as technology becomes entirely inflexible, $\eta^S \to \infty$, for example, because firms face binding capacity constraints. In such a situation, the change in marginal cost induces no change in output—and hence also no price change.

It is well-known that, under imperfect competition, it is possible for pass-through to exceed 100%. Lemma 2 makes precise that this occurs whenever $\widehat{\theta}^S(\xi^D - 1) \geq \eta^S(\varepsilon^D - \widehat{\theta}^S)$. Several things are needed: (i) there is market power $\widehat{\theta}^S > 0$; (ii) demand is log-convex $\xi^D > 1$ (equivalently, unit-superinelastic $\psi^D < 1$); and (iii) the elasticity of marginal cost η^S cannot be too large (for example, if $\eta^S > \max\{0, (\varepsilon^D - 1)^{-1}\} \equiv \underline{\eta}^S$ then $\rho < 1$ for any $\widehat{\theta}^S \in [0, 1]$ and $\xi^D < 2$).

4 Does competition increase pass-through?

What is the equilibrium impact of more competition on cost pass-through? Answering this question requires some care because varying the intensity of competition via $\widehat{\theta}^S$ can, in general, also affect the (equilibrium) values of the demand and cost parameters $(\varepsilon^D, \xi^D, \eta^S)$ as none of these are necessarily constants.

Two approaches are presented. First, the "between markets" approach compares pass-through in two different markets on a like-for-like basis in the cross section, where one market is more competitive than the other but identical in terms of $(\varepsilon^D, \xi^D, \eta^S)$. Second, as in Figure 1, the "within market" approach compares pass-through in the same market following an exogenous increase in its intensity of competition, taking into account any knock-on effects on $(\varepsilon^D, \xi^D, \eta^S)$.

Under both approaches, it will turn out that cost convexity makes the standard intuition—more competition raises pass-through—quite fragile.

4.1 Varying competition between markets

Consider two markets, 1 and 2, with different values of the intensity of competition, $\widehat{\theta}_1^S$ and $\widehat{\theta}_2^S$, where $\widehat{\theta}_1^S < \widehat{\theta}_2^S$. Firm conduct is more competitive in market 1 because there are more firms or because rivalry is more intense for the same number of firms.

The markets may differ in terms of their demand and cost *functions*. Lemma 2 makes clear that the relevant demand and cost conditions for pass-through are given by $(\varepsilon^D, \xi^D, \eta^S)$. The idea here is that an econometric analysis will control for any differences between the markets in terms of their values of $(\varepsilon^D, \xi^D, \eta^S)$.

Proposition 1 *Consider two markets* 1 *and* 2 *with the same demand conditions (as given by* ε^D, ξ^D*) and cost conditions (as given by* η^S*) where market* 1 *is more competitive than market* 2 *with* $\widehat{\theta}_1^S < \widehat{\theta}_2^S$. *Equilibrium cost pass-through is lower in the more competitive market* 1*,* $\rho(\widehat{\theta}_1^S) < \rho(\widehat{\theta}_2^S)$*, if and only if demand and cost conditions satisfy:*

$$\eta^S + \xi^D > 1,$$

which always holds for a sufficiently large elasticity of marginal cost η^S.

Proposition 1 yields the opposite of the standard intuition that more competition leads to higher pass-through. All else equal, whenever costs are sufficiently convex in that $\eta^S > 1 - \xi^D$, pass-through is *lower* in the market with more intense competition. For example, the condition always holds for pass-through $\rho|_{\tau \to 0}$ of a small new tax if demand is strictly convex $\xi^D > 0$ and costs are at least as convex as a quadratic cost function, $C(x_i) = kx_i^2$ (as then $\eta^S \geq 1$). More generally, the condition always holds for a sufficiently large (but finite) η^S, regardless of demand conditions and competitive intensity.[8]

With non-constant marginal cost, $\eta^S > 0$, more competition can therefore yield lower pass-through even in the "normal" case in which it lies below 100%. By contrast, in the special case with constant marginal cost, $\eta^S = 0$, analyzed in much of the existing literature the condition from Proposition 1 boils down to demand being log-convex $\xi^D > 1$. Then *both* markets feature pass-through in excess of 100% but it is closer to 100% in the more competitive market, $\rho(\widehat{\theta}_2^S) > \rho(\widehat{\theta}_1^S) > 1$.

What is driving this result? Recall that a less flexible production technology always means lower pass-through, $\partial\rho/\partial\eta^S < 0$. A key observation is that this effect is mitigated by market power in the following sense:

Lemma 3. *Equilibrium cost pass-through satisfies*

$$\frac{\partial}{\partial\widehat{\theta}^S}\left[\frac{\partial}{\partial\eta^S}\rho(\varepsilon^D, \xi^D, \eta^S, \widehat{\theta}^S)\right] \geq 0$$

if and only if the cost elasticity satisfies $\eta^S \leq [1 + (1 - \xi^D)(2\varepsilon^D - \widehat{\theta}^S)]/(\varepsilon^D - \widehat{\theta}^S)$*, for which* $\eta^S \leq 1 - \xi^D$ *is a sufficient condition.*

[8] In the limiting case as $\eta^S \to \infty$, pass-through converges to zero for any competitive intensity.

Lemma 3 shows that, for modest values of η^S, the pass-through function is supermodular in the cost elasticity and market power. A less flexible production technology means lower pass-through—and more strongly so for a more competitive market. This helps explains why, in markets with a fairly inflexible production technology, more competition can be associated with less pass-through.

Through the lens of incidence analysis, these results highlight the role of the producer surplus generated by a competitive market. In the "normal" case with pass-through below 100%, $\eta^S > 0$ is necessary for Proposition 1 to apply; this, in turn, means that the producer surplus associated with a competitive market is non-zero. By contrast, recent literature that employs pass-through as a tool for incidence analysis (see especially Weyl & Fabinger 2013) makes assumptions—specifically constant marginal cost and firm symmetry—that imply that a competitive industry always makes zero profits.

4.2 Varying competition within a market

Now consider the second approach: the same market, with the same demand and cost functions, is observed "over time" and competition (exogenously) intensifies, as measured by a lower value of $\widehat{\theta}^S$. Write the equilibrium price in terms of the conduct parameter $p(\widehat{\theta}^S)$, and think of the (equilibrium) values of the demand and cost parameters as $(\varepsilon^D(p(\widehat{\theta}^S)), \xi^D(p(\widehat{\theta}^S)), \eta^S(p(\widehat{\theta}^S)))$. How does more competition affect pass-through $\rho(\widehat{\theta}^S)$?

Let $\phi_i^S \equiv x_i C'''(x_i)/C''(x_i)$ be the elasticity of the *slope* of i's marginal cost which, given symmetry, will again be identical across firms with $\phi_i^S = \phi^S$ (also recalling that $\widehat{C}''(\cdot) = C''(\cdot)$ and $\widehat{C}'''(\cdot) = C'''(\cdot)$).

Proposition 2. *(a) Equilibrium cost pass-through is lower with more competition, $d\rho(\widehat{\theta}^S)/d\widehat{\theta}^S > 0$, if and only if demand and cost conditions and firm conduct satisfy:*

$$\frac{(\varepsilon^D - \widehat{\theta}^S)\eta^S}{\left[1 + \widehat{\theta}^S(1 - \xi^D) + (\varepsilon^D - \widehat{\theta}^S)\eta^S\right]}(\phi^S + \xi^D) > \frac{d}{d\widehat{\theta}^S}\left[\widehat{\theta}^S(1 - \xi^D)\right],$$

which always holds if the elasticity of marginal cost η^S and of the slope of marginal cost ϕ^S are sufficiently large;
(b) Equilibrium cost pass-through lies below 100%, $\rho(\widehat{\theta}^S) \leq 1$, and is lower with more competition $d\rho(\widehat{\theta}^S)/d\widehat{\theta}^S > 0$ if:

- *Demand is log-concave $\xi^D \leq 1$ and its curvature is non-decreasing $d\xi^D(p)/dp \geq 0$;*
- *Costs are sufficiently convex in that (η^S, ϕ^S) satisfy $(\varepsilon^D - \widehat{\theta}^S)\eta^S(\phi^S + 2\xi^D - 1) > (1 - \xi^D)[1 + \widehat{\theta}^S(1 - \xi^D)]$ for which $\eta^S > 0$ and $\phi^S > (1 - 2\xi^D)$ are then necessary.*

Proposition 2 delivers a similar conclusion to Proposition 1: Under plausible conditions, more competition reduces pass-through—and the standard intuition is overturned.

There is a simple set of sufficient conditions. First, demand is log-concave $\xi^D \leq 1$, which is a common assumption in economic theory (Bagnoli & Bergstrom 2005), and is more convex at a higher price $d\xi^D(p)/dp \geq 0$, which applies, for example, for any demand curve of the family $p(X) = \alpha - \beta X^\gamma$, which has constant curvature $\xi^D = 1 - \gamma$ (with parameters $\alpha > 0, \beta > 0, \gamma \geq 0$). This demand family corresponds to consumer valuations being drawn from a Generalized Pareto distribution (Bulow & Klemperer 2012). Second, firms' costs and marginal costs are sufficiently convex, that is, $\eta^S > 0 \Leftrightarrow C''(\cdot) > 0$ and $\phi^S > 0 \Leftrightarrow C'''(\cdot) > 0$ are both positive and sufficiently large.

To see the role of sufficient cost convexity, consider a market with a single firm and linear demand ($n = 1$, $\xi^D = 0$). Initially the firm is a price-taker ($\widehat{\theta}^S = 0$) and then it becomes a monopolist ($\widehat{\theta}^S = 1$). Let $x^c \equiv x(0)$ denote the competitive output and $x^m \equiv x(1)$ the monopoly output, where $x^m < x^c$. Cost pass-through under monopoly ρ^m is higher than with perfect competition ρ^c whenever:

$$\rho^m = \frac{1}{\left[2 + \dfrac{C''(x^m)}{\beta}\right]} > \frac{1}{\left[1 + \dfrac{C''(x^c)}{\beta}\right]} = \rho^c$$

which holds if and only if $\int_{x^m}^{x^c} C'''(y)dy = [C''(x^c) - C''(x^m)] > \beta$. So competition reduces pass-through if $C''(\cdot) > 0$, and $C'''(\cdot)$ is large enough. The condition from Proposition 2 provides a general result for the case of a small change in competitive intensity. The result of Figure 1, with $\rho^m = \frac{1}{2} > \rho^c = 0$, is nested where $C''(x^m) = 0$ (as marginal cost is constant around the monopoly output) and $C''(x^c) \to \infty$ (as the competitive industry produces at capacity K).[9]

More broadly, the theory with cost constraints can explain a "regime switch" in pass-through from above to below 100%. In particular, if the demand curve is log-convex ($\xi^D > 1$), then differences in the value of η^S—across markets and/or over time—can generate pass-through that somewhere or sometimes lies above and otherwise below 100%.

Example. A simple example illustrates how (i) the "between markets" and "within market" approaches can yield the same conclusion, (ii) the degree of cost convexity needed to overturn the standard intuition may be modest.

Demand is exponential $D(p) = \exp\left(\frac{\alpha - p}{\beta}\right) \Leftrightarrow p(X) = \alpha - \beta \ln X$, where $\alpha, \beta > 0$ are parameters, and so its curvature $\xi^D = 1$. Firms' cost functions are given by $C(x_i) = \delta x_i^\lambda$, with parameters $\delta > 0$ and $\lambda > 1$. Assuming the the cost shifter is initially zero, $\tau = 0$, this pins down the cost elasticity $\eta^S = \lambda - 1 > 0$. Using Lemma 2, equilibrium cost pass-through $\rho|_{\tau=0} = [1 + (\varepsilon^D - \widehat{\theta}^S)(\lambda - 1)]^{-1} < 1$ is incomplete—the "normal" case.[10]

[9] Strictly speaking, this involves a non-differentiability of the cost function around the capacity constraint K. However, the Figure 1 can be closely approximated using a marginal cost function $C'(x) = c - \omega \ln(1 - x/K)$ where $\omega > 0$ is a (small) parameter and $x/K \in [0, 1]$ is the firm's rate of capacity utilization.

[10] With log-linear demand $\xi^D = 1$ and constant marginal cost $\eta^S = 0$, cost pass-through $\rho = 1$ is

Between markets (Proposition 1): Conditional on the equilibrium values of the demand elasticity (ε^D) and the cost elasticity (via λ), it is immediate that the more competitive market 1 always has lower pass-through in the cross section, i.e., $\rho(\widehat{\theta}_1^S) < \rho(\widehat{\theta}_2^S)$ for $\widehat{\theta}_1^S < \widehat{\theta}_2^S$. This is the opposite of the standard intuition.

Within market (Proposition 2): By inspection, pass-through declines with more competition, $d\rho(\widehat{\theta}^S)/d\widehat{\theta}^S > 0$, whenever $\frac{d}{d\widehat{\theta}^S}[\widehat{\theta}^S - \varepsilon^D(p(\widehat{\theta}^S))] > 0$. It is easy to check that $d\varepsilon^D(p(\widehat{\theta}^S))/d\widehat{\theta}^S = \rho < 1$, so the condition of Proposition 2 always holds. This is again the opposite of the standard intuition.

5 Empirical implications

An emerging empirical literature has begun to explore the relationship between pass-through and market power (Miller, Osborne & Sheu 2017; Stolper 2018; Genakos & Pagliero 2019). These papers consider a single industry with multiple regional markets and—akin to Proposition 1—focus on the implications of cross-sectional differences in competition. While this literature also highlights the importance for pass-through of finer details on market conditions, it has so far engaged only little with the role of cost convexity.

Genakos & Pagliero (2019) study the relationship between competition and pass-through using 2010 daily retail prices for gasoline in isolated markets on the Greek islands. They argue that the firm-level marginal cost of gasoline stations is approximately constant in their short-run setting, i.e., $\eta^S \approx 0$. They find pass-through is just below 50% in monopoly markets and quickly rises towards 100% in markets with at least four firms. This is remarkably consistent with a textbook Cournot model with linear demand and constant marginal cost for which $\rho = 1/(1 + n^{-1})$ (Lemma 2 with $\theta = 1$, $\xi^D = 0$, $\eta^S = 0$).

Miller, Osborne & Sheu (2017) estimate pass-through rates around 130–180% using 30 years of annual data on the US Portland cement industry over the period 1980–2010. Their discussion of the institutional context also suggests that $\eta^S \approx 0$ is likely. By Lemma 2, pass-through above 100% means that demand must be log-convex ($\xi^D > 1$); by Proposition 1, cross-sectional pass-through is then unambiguously lower with greater competition. Using several measures of rivalry, Miller et al. (2017) find evidence across different regional markets that is consistent with this theoretical prediction.[11]

Stolper (2018) estimates pass-through using 2007 daily firm- and market-level price data for 10,000 gasoline retail stations in Spain. He finds an average cost pass-through

invariant to market power.

[11] Ganapati, Shapiro & Walker (2019) use estimate fuel cost pass-through in a panel of six homogenous-product US industries (boxes, bread, cement, concrete, gasoline, and plywood) and find large inter-industry heterogeneity. In their sample, cement is the most concentrated industry and has the highest pass-through rate (181%) but they do not attempt like-for-like comparisons between industries so their results do not speak directly to Proposition 1.

rate of around 90%, with the large majority of station-specific rates between 70–115%.[12] Moreover, greater market power—as proxied by a lower spatial density of competition and greater product branding—is strongly associated with *higher* pass-through. This finding appears to be potentially consistent with the condition of Proposition 1. However, as his analysis also assumes constant marginal costs, $\eta^S \approx 0$, the economic mechanism by which competition reduces pass-through may be more subtle.[13]

Looking ahead, it would be valuable for future research to use longer periods of higher-frequency data to study of the role of varying cost constraints—and test this paper's Propositions 1 and 2. It seems clear that, in practice, some industries are sometimes near a capacity constraint—though this is perhaps rare over (i) suitably chosen "short" time intervals or (ii) extended periods of a decade or more that are often studied by existing literature.[14]

A strong empirical research design could combine (i) variation that shifts market-wide marginal costs (leading to changes τ) with (ii) shocks to operational industry capacity such as capacity shutdowns due to regulatory interventions related to safety or maintenance (leading to changes in η^S).

6 Conclusions

Theoretical and empirical literature on imperfect competition typically assumes that firms have constant marginal costs. As a result, pass-through analysis as well as recent applications to incidence analysis in industrial organization, environmental economics and development economics have focused on demand-side properties. More competition then raises pass-through as long as it lies below 100%.

This paper has shown that this basic result is perhaps surprisingly fragile. If firms have increasing marginal costs, then more competition may reduce pass-through. A rough intuition is that a more competitive industry has higher output, and with convex costs is therefore "more exposed" to a cost increase. An immediate corollary is that the rate of pass-through of a demand shock (i.e., a uniform upward shift in consumers' willingness-to-

[12] The primary interest of Stolper (2018) lies in understanding the distributional implications of fuel cost shocks, with the main finding that wealthier regions tend have higher pass-through which makes the excise tax progressive.

[13] Proposition 1 makes precise that a valid empirical test must control for differences in demand and cost conditions, specifically in $(\varepsilon^D, \xi^D, \eta^S)$. A typical empirical pass-through study includes demand controls that plausibly account for variation in the demand elasticity ε^D. It is more challenging, however, to control for demand curvature ξ^D—which reflects heterogeneity in consumer valuations. This leads to possibility that empirical estimates could confound the impact of competition (differences in $\widehat{\theta}^S$) on pass-through with differences in higher-order demand conditions. Further complications would be introduced by the presence of horizontal product differentiation.

[14] Marion & Muehlegger (2011) obtain evidence consistent with the prediction from Lemma 2 that cost pass-through (ρ) decreases in the cost elasticity (η^S); in particular, they find that US gasoline markets very close to a capacity constraint exbibit markedly lower pass-through but do not test for the interaction with competition.

pay) may—again perhaps counterintuitively—be more pronounced in a more competitive market.[15]

In short, the market price will be more reflective of marginal cost in a more competitive market but it does not follow that price changes will necessarily be more reflective of cost changes.

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[15] This follows from the relationship: rate of cost pass-through + rate of demand pass-through = 1.

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Appendix

Proof of Lemma 1. The expression for $L \equiv \varepsilon^D[p(X) - \widehat{C}'(x)]/p(X)$ follows by rearranging (3) and using the definitions of ε^D and $\widehat{\theta}^S$. Differentiating (3) shows that:

$$\begin{aligned} \frac{dp(\widehat{\theta}^S)}{d\widehat{\theta}^S} &= p'(X)n\frac{dx}{d\widehat{\theta}^S} = p'(X)n\frac{p'(X)X}{-[p'(X)n + \theta p'(X) + \theta nxp''(X) - C''(x)]} \\ &= -p'(X)X\frac{n}{\left[(n+\theta) - \theta\xi^D - C''(x)/p'(X)\right]} > 0, \end{aligned} \tag{4}$$

where the denominator of this expression is positive because $(n + \theta) > \theta\xi^D$ given that $n \geq 1$, $\theta \in [0, 1]$ and $\xi^D < 2$ as well as $C''(x) \geq 0$ and $p'(X) < 0$.

Proof of Lemma 2. By construction, cost pass-through satisfies $\rho \equiv \frac{dp}{d\tau} = p'(X)n\frac{dx}{d\tau}$. Hence differentiating (3) yields:

$$\rho = \frac{p'(X)n}{[p'(X)n + \theta p'(X) + \theta n x p''(X) - C''(x)]} = \frac{n}{\left[(n+\theta) - \theta\xi^D - C''(x)/p'(X)\right]} > 0, \quad (5)$$

using the definition $\xi^D \equiv -Xp''(X)/p'(X)$ and where the denominator is again positive. Now rewrite the last term as follows:

$$\frac{C''(x)}{-p'(X)} = \frac{x\widehat{C}''(x)}{\widehat{C}'(x)}\frac{\widehat{C}'(x)}{p(X)}\frac{p(X)}{-Xp'(X)}\frac{X}{x} = \eta^S\frac{(\varepsilon^D - \theta/n)}{\varepsilon^D}\varepsilon^D n = \eta^S(\varepsilon^D - \widehat{\theta}^S)n, \qquad (6)$$

which uses Lemma 1 and the definitions $\varepsilon^D \equiv -p(X)/Xp'(X)$, $\eta_i^S \equiv x_i\widehat{C}''(x_i)/\widehat{C}'(x_i)$ (at symmetric equilibrium, where $\widehat{C}''(x_i) = C''(x_i)$), and $\widehat{\theta}^S \equiv (\theta/n)$. Combining (5) and (6) and some rearranging yields the expression for $\rho(\varepsilon^D, \xi^D, \eta^S, \widehat{\theta}^S)$.

Proof of Proposition 1. Given the assumptions, follows by inspection of Lemma 2.

Proof of Lemma 3. Differentiating the expression for equilibrium cost pass-through from Lemma 2 gives:

$$\frac{\partial}{\partial\eta^S}\rho(\varepsilon^D, \xi^D, \eta^S, \widehat{\theta}^S) = -\frac{(\varepsilon^D - \widehat{\theta}^S)}{\left[1 + (\varepsilon^D - \widehat{\theta}^S)\eta^S + \widehat{\theta}^S(1-\xi^D)\right]^2} < 0.$$

Differentiating again for the cross-partial effect gives:

$$\frac{\partial}{\partial\widehat{\theta}^S}\left[\frac{\partial}{\partial\eta^S}\rho(\varepsilon^D, \xi^D, \eta^S, \widehat{\theta}^S)\right] = \frac{\left[1 + (\varepsilon^D - \widehat{\theta}^S)\eta^S + \widehat{\theta}^S(1-\xi^D)\right] + 2(1-\xi^D-\eta^S)(\varepsilon^D - \widehat{\theta}^S)}{\left[1 + (\varepsilon^D - \widehat{\theta}^S)\eta^S + \widehat{\theta}^S(1-\xi^D)\right]^3}.$$

It is immediate that $\frac{\partial}{\partial\widehat{\theta}^S}\left(\frac{\partial}{\partial\eta^S}\rho\right) > 0$ if $\eta^S \leq 1 - \xi^D$ and some further rearranging shows that $\frac{\partial}{\partial\widehat{\theta}^S}\left(\frac{\partial}{\partial\eta^S}\rho\right) > 0 > 0$ if and only if $[1 + (1-\xi^D)(2\varepsilon^D - \widehat{\theta}^S)]/(\varepsilon^D - \widehat{\theta}^S)$.

Proof of Proposition 2. For part (a), differentiating the expression for pass-through from Lemma 2 shows that:

$$\frac{d\rho}{d\widehat{\theta}^S} > 0 \text{ if and only if } \frac{d}{d\widehat{\theta}^S}\left[\frac{1}{n}\frac{C''(x)}{-p'(X)}\right] < -\frac{d}{d\widehat{\theta}^S}\left[\widehat{\theta}^S(1-\xi^D)\right].$$

Expanding the first term gives:

$$\begin{aligned}
\frac{d}{d\widehat{\theta}^S}\left[\frac{1}{n}\frac{C''(x)}{-p'(X)}\right] &= \frac{1}{n}\frac{dX}{d\widehat{\theta}^S}\left[\frac{\frac{1}{n}C'''(x)-[-p''(X)]C''(x)}{[-p'(X)]^2}\right] \\
&= \frac{1}{n}\frac{dX}{d\widehat{\theta}^S}\frac{1}{X}\left[\frac{xC'''(x)}{C''(x)}+\frac{p''(X)X}{-p'(X)}\right]\frac{C''(x)}{-p'(X)} \\
&= -\frac{1}{n}\frac{dp}{d\widehat{\theta}^S}\frac{1}{-Xp'(X)}\left[\frac{xC'''(x)}{C''(x)}+\frac{p''(X)X}{-p'(X)}\right]\frac{C''(x)}{-p'(X)} \\
&= -\left[\frac{1}{n}\frac{C''(x)}{-p'(X)}\right](\phi^S+\xi^D)\rho,
\end{aligned}$$

where the last step uses the definitions $\xi^D \equiv -Xp''(X)/p'(X)$ and $\phi_i^S \equiv x_iC'''(x_i)/C''(x_i)$ (at symmetric equilibrium) and combines the result for $dp/d\widehat{\theta}^S$ from Lemma 1, see (4), with the result for ρ from Lemma 2, see (5). Now using $\dfrac{1}{n}\dfrac{C''(x)}{-p'(X)} = (\varepsilon^D - \widehat{\theta}^S)\eta^S$ from (6) and the expression for ρ from Lemma 2 gives:

$$\frac{d}{d\widehat{\theta}^S}\left[\frac{1}{n}\frac{C''(x)}{-p'(X)}\right] = -\frac{(\varepsilon^D-\widehat{\theta}^S)\eta^S}{\left[1+\widehat{\theta}^S(1-\xi^D)+(\varepsilon^D-\widehat{\theta}^S)\eta^S\right]}(\phi^S+\xi^D),$$

and the condition follows immediately as claimed.

For part (b), under the assumption $d\xi^D/dp \geq 0$, it follows that $\frac{d}{d\widehat{\theta}^S}[\widehat{\theta}^S(1-\xi^D)] \leq (1-\xi^D)$ since $dp/d\widehat{\theta}^S > 0$ by Lemma 1. So it is sufficient for the condition from part (a) that:

$$\frac{(\varepsilon^D-\widehat{\theta}^S)\eta^S}{\left[1+\widehat{\theta}^S(1-\xi^D)+(\varepsilon^D-\widehat{\theta}^S)\eta^S\right]}(\phi^S+\xi^D) > \frac{d}{d\widehat{\theta}^S}[\widehat{\theta}^S(1-\xi^D)] \geq (1-\xi^D),$$

which can be rearranged as claimed.