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A toolkit for setting and evaluating price floors[☆]

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ABSTRACT

Regulators often impose price floors to protect producers from suspected market power by intermediaries. We present a toolkit for predicting, estimating, and explaining the effect of price floors on output and the distribution of welfare. We apply this toolkit to the Colombian road freight sector, taking advantage of rate floors that intended to protect carriers from low freight rates paid by intermediaries. We find that policymakers could have predicted the effect of price floors on quantities: a reduction in quantities for the routes and products for which rate floors were binding. After their implementation in 2017, rate floors benefited carriers but reduced total welfare by 12% of market revenue.

1. Introduction

Governments concerned with inefficiency or inequality often impose price controls, such as price floors or ceilings, to counteract market power by intermediaries or distributors. Such is the case in markets for agricultural products, groceries, gasoline, transportation, banking, and alcoholic beverages (Wright and Williams, 1988; Eslava, 2000; Carranza et al., 2015; Ferrari et al., 2018; Aparicio and Cavallo, 2021; Griffith et al., 2022). Policy makers with limited resources and short design time frames might rely on simple rules of thumb to set the level of price floors or ceilings. In Colombia and Spain, for example, policy makers calculate freight rate floors by extrapolating past freight rates or measuring accounting costs.[3] These rules of thumb might result in price floors that are too high, reducing traded quantities and market efficiency relative to a free market.

This paper provides scholars and policymakers with a toolkit for setting and evaluating price floors in markets with intermediaries. Consider a prospective floor on the price that intermediaries pay to producers in a given market. The toolkit provides (i) a rule to predict, ex-ante, whether the price floor will reduce equilibrium quantities; (ii) a test to evaluate, ex-post, whether the price floor reduced equilibrium quantities; (iii) a test to evaluate whether the unregulated market was competitive; (iv) estimators for the elasticities of supply and demand. These elasticities are useful to estimate the incidence of price floors among consumers, intermediaries, and producers. We use our toolkit to predict ex-ante, and evaluate ex-post, the impact of freight rate floors in the Colombian road freight sector.

Our empirical toolkit relies on a theoretical model in which intermediaries hold market power over producers and consumers. We use the model to study floors on the upstream price; i.e., the price that intermediaries pay to producers. The main purpose of our theoretical model is to provide reduced form formulas that can be applied by scholars and policy makers with limited resources, data, and time—such common limitations prevent the estimation of complex structural

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models but permit the estimation of our simple model. For example, we provide point-estimates for the elasticity of demand, even in the absence of data on the downstream prices charged by intermediaries to consumers.

The main behavioral assumption of our model is that intermediaries operate as in a Cournot model by choosing quantities. This assumption is appropriate for sectors in which capacity constraints are important, such as logistics, retail, agriculture, and energy storage and distribution. Within this framework, intermediaries hold market power over both producers and consumers. Enacting a price floor on upstream prices eliminates market power over producers but can increase marginal costs for intermediaries. The net effect on downstream prices and equilibrium quantities depends on the level of the price floor, the number of intermediaries, and the elasticities of supply and demand. Notably, our equilibrium conditions reveal that predicting the effect on prices and quantities does not necessitate knowledge of the elasticity of demand; a conjecture regarding the elasticity of supply suffices. Moreover, we present formulas to recover the elasticities of supply and demand from the effect of the price floor on prices and quantities.

The main limitation of the model is to omit the entry and exit of intermediaries, as this would create equilibria indeterminacy. Hence, we do not consider mechanisms that operate in the long run, such as large changes in the market structure of the industry through innovation or entrant selection, as in Carranza et al. (2015). While the goal of the model is to support empirical work, the model provides novel theoretical results that are supplementary contributions from our paper: price floors on upstream prices can increase or decrease downstream prices, optimal price floors under market power are lower than perfect competition prices, and there are multiple equilibria – some more efficient than others – even in the absence of intermediaries' entry and exit.

The empirical component of our toolkit depends on the following counterfactual: what would have been the equilibrium quantities and prices in absence of the price floor? Our toolkit is agnostic of the empirical strategy that practitioners would use to estimate this counterfactual. In our application, the enactment of floors on freight rates provides two suitable control groups: (i) products for which the rate floor is not binding, despite being transported through routes with rate floors, and (ii) routes with no rate floors, with the same origin and similar characteristics as those of the routes with rate floors. We use the first control group as the basis for a difference-in-difference approach to estimate the effect of freight rate floors on prices and shipped quantities. We incorporate the second group into a triple difference specification that yields estimates similar to those of the double difference specification.

Using data preceding the enactment of the rate floors, we predict that rate floors would reduce shipped quantities for at least 58% of the products with binding price floors. Using data posterior to the enactment of the price floors, we show that the prediction was correct: shipped tonnage fell for 87% of the products with binding price floors; the average reduction in tonnage across products was 37%. Shipped tonnage fell because most intermediation markets were competitive. Across product-routes, we estimate a median elasticity of demand of 1.4 and a supply elasticity of 1.7. Given our estimated distribution of elasticities, we calculate that price floors cost shippers 26% of market revenue, cost intermediaries 6% of market revenue, and benefited carriers by 20% of market revenue. Overall, price floors created a deadweight loss of 12% of market revenue.

We contribute to the empirical literature on price controls. Ex-post estimates of the effect of price controls on prices, quantities, innovation, and productivity vary widely across papers, both in markets for goods and markets for labor.[4] Opposite results in different markets might be explained by distinct levels of market power relative to the price floor or the price ceiling. Our contribution to this literature is threefold. First, we formally consider market power by intermediaries. Second, we successfully predict the effect of price floors on output. Third, we study the incidence of price floors.

Our incidence calculations rely on estimates of the demand and supply elasticities, which we obtain from the response of prices and quantities to price floors and local protests.[5] Hence, our paper is also related to the literature that estimates markups and markdowns, as well as supply and demand elasticities, using other sources of variation.[6] Our model further implies that estimating the demand elasticity as the ratio of exogenous variations in quantities and upstream prices is biased towards zero since this procedure ignores the market power of intermediaries. We propose an alternative estimator derived from our theoretical model.

Freight rate controls are common in the transportation industry. Road freight in the US was subject to rate controls from 1935 until the transportation industry was deregulated in the 1980s (Poisler and Greenberg, 2020). Multiple papers study the overall impact of deregulation on road and rail freight in the US but do not study the specific effects of price floors (Keeler, 1989; Ying, 1990; Ying and Keeler, 1991; Daniel and Kleit, 1995; Boylaud, 2000; Boyer, 1987; Wilson and Wolak, 2016; Mayo and Willig, 2019; Montero and Finger, 2020). We contribute to this literature by using modern empirical methods to study the costs of price floors in the trucking industry.

We also contribute to the literature on the political economy and the industrial organization of the Colombian road freight sector. Eslava (2000) studies the political economy of the sector during the 1990s, when carrier associations and the Colombian government negotiated floors on the freight rates for each route. Using aggregate data, Eslava argues that the exercise of oligopsony power was low at the time. Huari (2015) documents the political economy of the regulation of the road freight sector between 2001 and 2014. Our contribution to this literature is twofold. First, we use the enactment of price floors as a policy experiment to show that intermediation markets were indeed competitive in the regulated routes. Second, we study the distributive effect of price floors among shippers, intermediaries, and carriers.

2. Theory

We start by assuming n firms that intermediate between buyers (shippers) and sellers (carriers). Buyers and sellers are price-takers; their choices are represented by demand and supply functions with constant price elasticities: $Q^d = k^d P^{-\epsilon^d}$ and $Q^s = k^s W^{\epsilon^s}$. Let $P(Q)$ and $W(Q)$ be their inverse functions. Intermediaries operate as in a Cournot model by choosing quantities. Let q_i be the trips intermediated by firm i. In equilibrium, $Q^d = Q^s = \sum_{i=1}^{n} q_i$.

Benefits for intermediary i are given by:

$$\pi_i(q_i) = \max_{q_i} [P(Q) - W(Q) - c_i] q_i \tag{1}$$

where c_i is an exogenous component of the marginal cost of intermediation that differs across intermediaries.

[4] See, for example: Card and Krueger (1995), Bell (1997), Maloney and Mendez (2004), Neumark and Wascher (2006), Kyle (2007), Brekke et al. (2011, 2015), Carranza et al. (2015), Aparicio and Cavallo (2021), Clemens and Wither (2019), Lavecchia (2020), Drucker et al. (2021); and Gregory and Zierahn (2022)

[5] Variation in price floors allows for point-estimates of demand elasticities and set-estimates of supply elasticities. Exogenous variation in local protests allows for point-estimates of supply elasticities.

[6] For example, characteristics of competing products (Berry et al., 1995), prices in other markets (Hausman, 1996; Nevo, 2001), wage changes in the public sector (Staiger et al., 2010; Falch, 2010), wage differences across firms (Bassier et al., 2022), input shares and input price shocks (De Loecker et al., 2016; Tortarolo and Zarate, 2020), export destinations and exchange rate shocks (Amodio and de Roux, 2021), and tax rates (Weyl and Fabinger, 2013; Zoutman et al., 2018; Adachi and Fabinger, 2022; Dearing, 2022).

The first order condition for intermediaries is:

$$\underbrace{\left(P(Q)+P'(Q)q_i\right)}_{\text{Marginal Revenue}}-\underbrace{\left(W(Q)+W'(Q)q_i+c_i\right)}_{\text{Marginal Cost}}=0 \tag{2}$$

We assume that $\epsilon^d \geq 1$, which is sufficient for the second order condition to hold.[7]

Let $\bar{c}=\sum_i c_i/n$. Summing Eq. (2) over all intermediaries, rearranging and simplifying, we obtain the price charged by intermediaries in a free market equilibrium[8]:

$$P^{FM}=\frac{\left(1+\frac{1}{n\epsilon^s}\right)W^{FM}+\bar{c}}{1-\frac{1}{n\epsilon^d}} \tag{3}$$

Consider a floor for the price that intermediaries pay to sellers in the upstream market, W^{PF}, such that the price floor is binding: $W^{PF}>W^{FM}$. Fig. 1 illustrates the case of a single intermediary that is both a monopolist and a monopsonist.

In the general case, benefits for intermediary i facing price floor W^{PF} are:

$$\pi_i(q_i;q_-,W^{PF})=\max_{q_i}\begin{cases}[P(Q)-W^{PF}-c_i]q_i & \text{if } Q\leq Q^s(W^{PF})\\ [P(Q)-W(Q)-c_i]q_i & \text{if } Q>Q^s(W^{PF})\end{cases} \tag{4}$$

In Eq. (4), intermediaries are price-takers in the upstream market as long as $Q \leq Q^s\left(W^{PF}\right)$. If $Q > Q^s\left(W^{PF}\right)$, intermediaries must pay $W > W^{PF}$. In consequence, the marginal cost of intermediaries is discontinuous at $Q^s(W^{PF})$. This discontinuity allows for multiple equilibria when the price floor is close to the free market price, as we show in Proposition 1:

Proposition 1 (*Equilibria for a Price Floor Near W^{FM}*). *Suppose $W^{FM} < W^{PF} < \hat{W}$, where $\hat{W}$ satisfies $P\left(Q^s\left(\hat{W}\right)\right)\left(1-\frac{1}{n\epsilon^d}\right)=\hat{W}+\bar{c}$. Then:*

1. *There are multiple equilibria if $n>1$*
2. *Every equilibrium satisfies $Q=Q^s\left(W^{PF}\right)$*
3. *If $n>1$ and c_i is heterogeneous, some equilibria are more efficient than others.*

Proof. See Appendix A.1. □

Corollary. $W^{FM}<W^{PF}<\hat{W} \Rightarrow Q^{FM}<Q^{PF}$

A price floor increases equilibrium quantities, relative to the free market, when the price floor is above but near the free market price. In that case, there are multiple equilibria with the same aggregate output but different aggregate costs. Efficiency across equilibria is heterogeneous because multiple intermediaries can increase their output in response to the floor, but some intermediaries have higher idiosyncratic costs, c_i, than others.

When $W^{PF} > \hat{W}$, there is a unique equilibrium. Given the price floor, the downstream price is given by:

$$P^{PF}=\frac{W^{PF}+\bar{c}}{1-\frac{1}{n\epsilon^d}} \tag{5}$$

We now identify the level of a price floor that maximizes output in equilibrium:

Proposition 2 (*Optimal Price Floor*). *W^{PF} maximizes output if and only if $P\left(Q^s\left(W^{PF}\right)\right)\left(1-\frac{1}{n\epsilon^d}\right)=W^{PF}+\bar{c}$.*

Proof. Define $\hat{W}$ as in Proposition 1. If $W^{PF}<\hat{W}$, Q is increasing in W^{PF} because of Proposition 1. If $W^{PF}>\hat{W}$, P^{PF} is increasing in W^{PF} (Eq. (5)). Hence, if $W^{PF}>\hat{W}$, Q is decreasing in W^{PF} because the demand curve slopes downwards. Hence, $W^{PF}=\hat{W}$ maximizes output. □

Remark (*Features of the Optimal Price Floor*). The optimal price floor, $\hat{W}$, is increasing in n. However, it is bounded above by the free-market price that would prevail if the intermediation market was competitive, i.e., $W' : P\left(Q^s\left(W'\right)\right)=W'+\bar{c}$.

Proposition 2 implies that recovering the optimal price floor before enacting the price floor is very difficult: the policy maker would need to know the average intermediation cost ($\bar{c}$), as well as the demand and supply shifters and elasticities ($k^s, k^d, \epsilon^s, \epsilon^d$). Therefore, we study a different question that is much easier to solve ex-ante by a policymaker, as we will prove: what is the level of the price floor that reduces output relative to a free market? In other words, when is a price floor too high according to the no-harm principle?

We first consider the effect of the upstream price floor on the downstream price paid by buyers (shippers). The sign of this effect depends on the number of competitors and the supply elasticity:

Lemma 1 (*Effect on Downstream Prices*).

$$P^{PF}>P^{FM} \iff W^{PF}>\left(1+\frac{1}{n\epsilon^s}\right)W^{FM}$$

Proof. Subtracting Eq. (3) from Eq. (5), we obtain:

$$P^{PF}-P^{FM}=\frac{W^{PF}-\left(1+\frac{1}{n\epsilon^s}\right)W^{FM}}{1-\frac{1}{n\epsilon^d}}$$

The numerator is positive if an only if $\frac{W^{PF}}{W^{FM}}>1+\frac{1}{n\epsilon^s}$ □

We now study the effect of price floors on quantities and, hence, efficiency. Proposition 3 provides a necessary and sufficient condition for a decrease in quantities.

Proposition 3 (*Effect on Quantities*).

$$Q^{PF}<Q^{FM} \iff W^{PF}>\left(1+\frac{1}{n\epsilon^s}\right)W^{FM}$$

Proof. Since the demand curve slopes downward, $Q^{PF}<Q^{FM} \iff P^{PF}>P^{FM}$. The Proposition follows from Lemma 1. □

Corollary (*Effect on Quantities in a Competitive Market ($n\to\infty$)*).

$$\lim_{n\to\infty} Q_n^{PF} < \lim_{n\to\infty} Q_n^{FM}$$

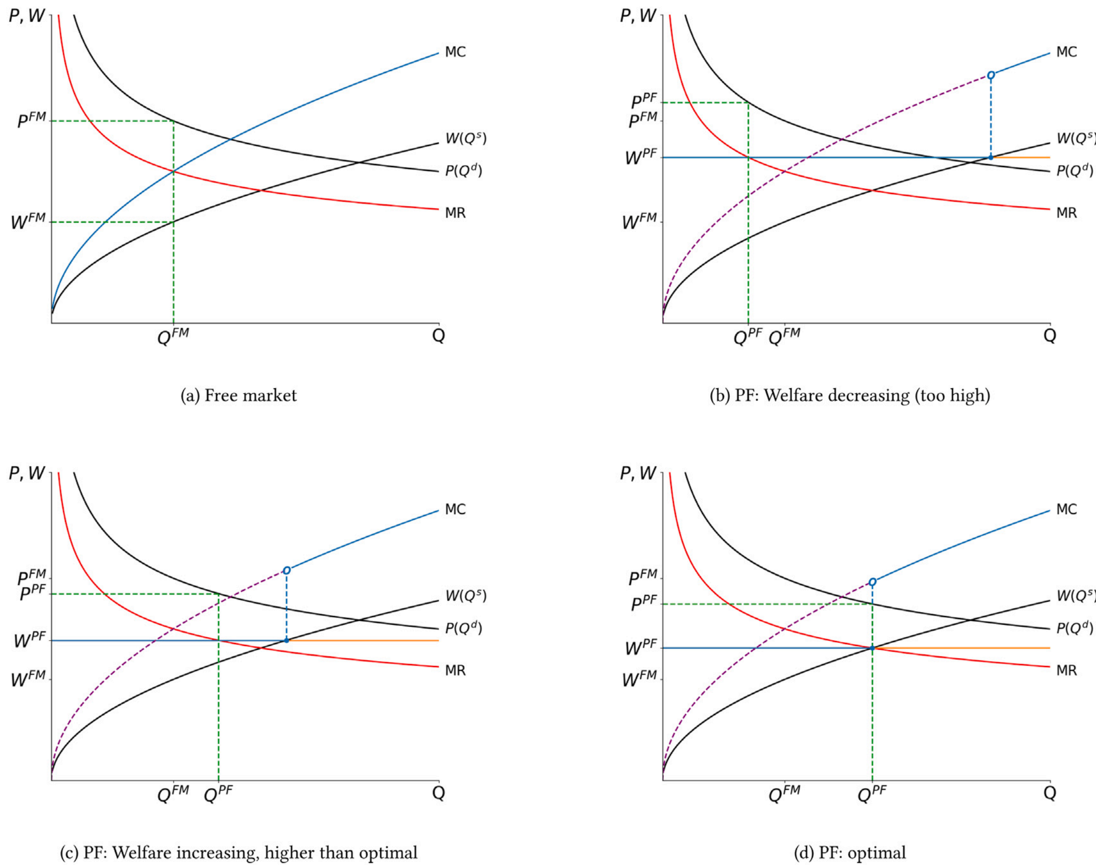
Proof. $\lim_{n\to\infty}\left(1+\frac{1}{n\epsilon^s}\right)=1$ and, by definition, $W_n^{PF}>W_n^{FM}$. The Corollary follows from Proposition 3. □

If a price floor is above the threshold of Proposition 3, there is a decrease in quantities relative to the free market. In this sense, the price floor is too high. If the price floor is below the threshold, there is an increase in quantities, which implies an increase in economic surplus. As the market becomes more competitive, i.e., as n becomes larger, the upper bound from Proposition 3 becomes smaller. In the limit ($n\to\infty$), any binding price floor reduces quantities in equilibrium (Proposition 3).

Proposition 3 is remarkable because the threshold only depends on the number of intermediaries (n), the elasticity of supply (ϵ^s), and the upstream free market price (W^{FM}). This is a much lighter requirement

[7] The second order condition is:
$P'(Q)[2-(1+1/\epsilon^d)(q_i/Q)]-W'(Q)[2+(1/\epsilon^s-1)(q_i/Q)]<0$. The subtrahend is positive – the marginal cost is increasing – so the second order condition holds if $\epsilon^d \geq 1$.

[8] This free market solution is a generalization of Beard (2015), who solves a Cournot model of a one-side market with isoelastic demand. The equilibrium price and quantity do not depend on the full distribution of c_i; only on $\sum_i c_i$. This result is a special case of Bergstrom and Varian (1985).



(a) Free market

(b) PF: Welfare decreasing (too high)

(c) PF: Welfare increasing, higher than optimal

(d) PF: optimal

Fig. 1. Example–Intermediary is both a monopolist and a monopsonist
Buyers and sellers are price-takers, with willingness to pay/accept given by the demand and supply curves, $P(Q^d)$ and $W(Q^s)$. There is a single intermediary with $c_i = 0$. In subfigure 1(a), there is no price floor. The intermediary maximizes profits by equalizing its own marginal revenue and marginal cost curves, MR and MC, which are derived from the demand and supply curves. Hence, the intermediary chooses Q^{FM} units of output, charges buyers P^{FM} for each unit, and pays sellers W^{FM} for each unit. Economic profits for the intermediary are given by $Q^{FM}(P^{FM} - W^{FM})$. In subfigure 1(b), there is a price floor, W^{PF}, in the upstream market between intermediaries and sellers. The intermediary is a price-taker in the upstream market as long as $Q \leq Q^s(W^{PF})$, so its marginal cost is W^{PF} in that range. Hence, the intermediary chooses Q^{PF} by solving $W^{PF} = MR$. In this case, $Q^{PF} < Q^{FM}$ because W^{PF} is higher than the intersection of MR and the free-market MC (dotted curve). In subfigure 1(c), W^{PF} is lower than that intersection, so $Q^{PF} > Q^{FM}$. In Subfigure 1(d), the policy maker increased quantities by reducing the price floor until the point in which MR intersects supply, $W^{PF} = MR = W(Q^s)$. This is the price floor that maximizes quantities, and hence, welfare. Further decreases in the price floor would decrease quantities along the supply curve.

for policymakers than the optimal price floor of Proposition 2. In Section 5, we use Proposition 3 to predict, ex-ante, which routes and products will experience reductions in quantities in response to price floors.

For the remaining of this section, suppose for tractability that $\bar{c} = 0$. The following lemma will be useful:

Lemma 2 (*Closed-form Expression of the Effect on Quantities*).

$$\frac{Q^{PF}}{Q^{FM}} = \left[\left(1 + \frac{1}{n\epsilon^s}\right)\frac{W^{FM}}{W^{PF}}\right]^{\epsilon^d} \tag{6}$$

Proof. Replace Eqs. (3) and (5) in the demand function. □

We now use price floors to assess whether intermediation markets are competitive or not.

Proposition 4 (*Impact of n on the Effect on Quantities*).

$$\frac{\mathrm{d}\left(Q^{PF}/Q^{FM}\right)}{\mathrm{d}n} > 0 \textit{ and } \lim_{n\to\infty} \frac{\mathrm{d}\left(Q^{PF}/Q^{FM}\right)}{\mathrm{d}n} = 0$$

Proof. See Appendix A.2. □

Proposition 4 shows that, with market power, the effect of price floors on quantities depends on the number of intermediaries.[9] However, as the market becomes competitive, the marginal impact of additional competitors becomes smaller. In the limit ($n \to \infty$), additional competitors have no impact on the effect of price floors. In Section 6, we use Proposition 4 to test the competitiveness of the intermediation sector, which in turn explains the ex-post effect of price floors on quantities.

We now find an expression for the demand elasticity as a function of the price floor's effects on quantities and upstream prices.

Proposition 5 (*Identification of the Elasticity of Demand*).

$$\epsilon^d = -\frac{ln\left(\frac{Q^{PF}}{Q^{FM}}\right)}{ln\left(\frac{W^{PF}}{W^{FM}}\right) - ln(1 + 1/n\epsilon^s)}$$

Proof. Solve for ϵ^d from Lemma 2 □

[9] This result is related to the concept of the strategic supply curve of a market with no intermediaries (Menezes and Quiggin, 2020).

Corollary (*Identification of the Elasticity of Demand in Competitive Markets*).

$$\lim_{n\to\infty} \epsilon^d = -\frac{ln\left(\frac{Q^{PF}}{Q^{FM}}\right)}{ln\left(\frac{W^{PF}}{W^{FM}}\right)}$$

Proof. Take the $\lim_{n\to\infty}$ on both sides of Proposition 5. □

Proposition 5 permits the estimation of the demand elasticity in oligopsonistic markets. Remarkably, we do not need data on *downstream* prices. We only need to know the effect of the price floor on quantities (Q^{PF}/Q^{FM}), the effect of the price floor on *upstream* prices (W^{PF}/W^{FM}), the supply elasticity (ϵ^s), and n. Furthermore, if the market is competitive ($n \to \infty$), the elasticity of demand can be estimated as the ratio between the effects on quantities and upstream prices. This occurs because economic profits for intermediaries are zero in perfect competition, so the variation in upstream prices equals the variation in downstream prices. However, if the market is oligopsonistic, ignoring the term $-ln(1 + 1/n\epsilon^s)$ biases the elasticity of demand towards zero.

Finally, we provide a lower bound for the elasticity of supply depending on the effect of price floors on quantities.

Proposition 6 (*Partial Identification of the Elasticity of Supply*).

$$\epsilon^s > \frac{1}{n}\left(\frac{1}{\frac{W^{PF}}{W^{FM}} - 1}\right) \iff Q^{PF} < Q^{FM}$$

Proof. Solve for ϵ^s from Proposition 3 □

We use Propositions 5 and 6 in our incidence analysis of Section 8.

3. Economic and regulatory context

Trucks carry 96% of tonnage shipped within Colombia, excluding coal and oil (Ministerio de Transporte, 2020). Most firms ship goods through the transport market rather than relying on their own trucks: only 19% of commercial firms, 27% of industrial firms, and 27% of agricultural firms own a truck (Departamento Nacional de Planeación, 2018, p. 694)

The Colombian long-haul market involves three types of participants: shippers (consignors), intermediaries (brokers or freight forwarders), and independent carriers.[10] Colombian regulation prevents shippers from hiring independent carriers directly, except for the transport of few product categories like beer and agricultural goods.[11] Instead, shippers must hire intermediaries.[12] Intermediaries may either use their own trucks or subcontract independent carriers. Independent carriers constitute a significant portion of the Colombian market, representing 80% of trucks and 90% of shipping capacity, with truck ownership characterized by high fragmentation (Allen et al., 2024).

Both intermediaries and independent carriers have the freedom to operate across the entire Colombian territory, but they often focus on trips near their headquarters or hometowns (Allen et al., 2024). Hence, shipping transactions occur in overlapping markets defined by specific routes, where a route is defined as a pair of municipalities indicating the origin and destination of the shipment.

There are two prices in this market. The upstream price is the freight rate paid to independent carriers by intermediaries.[13] The downstream price is the freight rate charged by intermediaries to shippers.[14]

The intent to protect carriers from low freight rates has driven public policy in Colombia since the 1990s (Eslava, 2000; Huari, 2015). Two policies have been enacted intermittently: (i) a scrapping scheme meant to restrict the supply of trucks and (ii) freight rate floors. In principle, since 2013, intermediaries must pay higher freight rates than the cost of a regular carrier for each route. Estimates of such cost are calculated and published by the Ministry of Transport. In practice, rate floors based on estimated costs were not enforced during the period of our study: in the median route in our sample, 43% of trips had rates under the Ministry's estimates. Under-the-floor rates could be audited by the government, in which case intermediaries had to demonstrate lower travel costs than the Ministry's estimates.[15] However, audits and fines were unlikely.[16] This lack of enforcement motivated carriers' strikes in 2015 and 2016.

As a part of the agreement that ended the strike in 2016, the government enacted rate floors in 22 long-haul routes.[17] In particular, the government set a minimum rate per ton for trips paid to independent carriers by intermediaries (upstream price). The government's stated rationale was that freight rates in those routes "had a downtrend or were below estimated costs" in early 2016.[18] These routes are among the most transited, accounting for 5% of Colombian road freight trips in 2016. These are the routes and price floors that we study.

4. Data

Our dataset was provided by the Ministry of Transport in 2017. The data covers the market between intermediaries and independent carriers, which accounts for 90% of shipping capacity in the Colombian regulated market. For each trip between 2014 and 2017, we know the price paid by intermediaries to independent carriers, the date, the tonnage transported, the capacity of the truck, the Harmonized System (HS) product classification of the good being transported, the origin of the trip, and its destination.[19] We were not able to access trip-level data for 2018. In addition, we do not observe the price charged by intermediaries to shippers, which highlights an advantage of our theoretical results: propositions 3–6 do not depend on the downstream price.

We do not observe identifiers for intermediaries at the trip level before 2017; we only observe the number of intermediaries by route. However, we observe the number of intermediaries by product-route in 2019, which we use for our analyses at the product-route level. This might have been a source of concern if price floors had induced the exit of intermediaries in 2016. This concern is ameliorated by a stable number of intermediaries across routes between 2015 and 2019 (Fig. A.8 in the appendix).

Our data-cleaning procedure focused on removing freight rate errors. We dropped trips out of the 1–99 percentiles of the freight rate per ton distribution within each route. We also dropped trips with less than 3 tons of cargo, which is the cargo capacity for the smallest trucks.

[10] In Spanish: *generadores de carga*, *empresas de transporte* and *propietarios de vehículos*. We translate *empresas de transporte* as freight forwarders because their role in Colombian regulation is closer to that of freight forwarders in U.S. regulation, per 49 U.S.C. 13102.

[11] Intermediaries are a required actor in transport contracts (Decree 1079 of 2015, chapter 7, article 2.2.1.7.3). For exceptions, see decree 2044 of 1988.

[12] Intermediaries are licensed by the Ministry of Transportation after demonstrating shareholders' equity of around 250 thousand dollars (Decree 1079 of 2015). Intermediaries play a vital role in ensuring regulatory compliance, obtaining insurance, completing required paperwork, and guaranteeing contract fulfillment. They can also provide additional services such as security or tracking during transportation (Mesa-Arango et al., 2022).

[13] The upstream price is known in Colombian regulation as *valor pagado*.

[14] The downstream price is known in Colombian regulation as *flete*.

[15] Memorando 2015101012461.

[16] Transport Superintendency, Derecho de petición 20175600385612

[17] "Acuerdo para la reforma estructural del transporte de carga por carretera", July 22, 2016; Resolutions 3437–3442 of 2016

[18] In Section 6, we show that our control and treatment groups have the same pre-trends for the outcomes that we study.

[19] Origins and destinations are recorded at the municipality level. The HS codes are at the 4-digit level.

Table 1
Descriptive statistics for intervened routes (2015/08–2016/07).

Intervened routes	Tons (total)	Trips (total)	Trucks (#)	Truck owners (#)	Intermediaries (#)	Rate per ton (average)	Rate floor (after 2016/07)	Trips below rate floor (%)
Buenaventura – Cali	868,933	38,288	6001	3505	352	86	47	36.5
Cucuta – Barranquilla	625,725	18,933	4367	2969	128	81	79	66.0
Santa Marta – Bucaramanga	536,408	16,025	2538	1713	88	88	90	78.3
Bogota – Cartagena	301,125	23,621	8877	5485	624	227	102	10.6
Bogota – Cali	257,169	22,007	10,210	6568	642	157	68	12.1
Bogota – Buenaventura	147,818	11,221	4763	2950	357	116	79	30.2
Medellin – Cartagena	121,136	7563	4597	2757	339	149	78	17.2
Manizales – Bogota	80,503	4183	1838	1234	153	118	77	35.3
Cali – Barranquilla	77,866	4439	3502	2163	242	288	151	23.9
Medellin – Barranquilla	73,194	5376	4586	2849	338	184	78	14.8
Manizales – Medellin	67,005	3137	1221	844	91	86	54	40.9
Manizales – Buenaventura	56,760	3978	1362	955	47	102	61	29.3
Bogota – Ipiales	41,563	3517	1409	1163	244	279	144	6.3
Manizales – Barranquilla	39,629	1424	655	449	51	150	104	62.0
Medellin – Buenaventura	39,020	3089	2508	1653	185	120	78	22.9
Buenaventura – Pitalito	10,045	315	156	119	28	127	130	91.7

We describe our data in Section 4. Rates are in thousands of 2016 Colombian pesos.

Finally, we exclude products under the "mail delivery" category, as pricing for this category differs from other categories.

The government enforced freight rate floors in 22 routes as of 2016. These routes have many competitors: the route with the median number of trips in our data, Medellín – Buenaventura, is operated by 2508 trucks, 1653 carriers and 185 intermediaries (Table 1). Rate floors apply to solid freight, not to liquid freight. We exclude 5 out of the 22 routes from our analysis because most trips in those routes carry liquid products or solid products for which the price floors were not binding. We drop an additional route because there were only two product categories in its control group and one product category in its treatment group, so results would be too dependent on unobserved factors driving these three product categories in that route. In consequence, we only consider 16 of the 22 routes for which price floors were enacted.

Freight rate floors are lower than average freight rates for 14 out of 16 routes (Table 1). Furthermore, for most routes, price floors are lower than the typical costs estimated by the Ministry. Hence, price floors are only binding in practice for a subset of products with low transport costs. This fact is crucial for our empirical strategy, which we implement at the product-route level.

5. Ex-ante policy evaluation

Policymakers can use Proposition 3 to predict whether a price floor will decrease quantities in a given market. If the price floor is higher than the threshold, quantities will decrease. Otherwise, quantities will increase. We use Proposition 3 to predict the effect of freight rate floors (price floors) on tonnage (quantities) at the product-route level.

The threshold in Proposition 3 depends on the level of freight rates under the free market. These rates refer to the counterfactual ex-post scenario in which the rate floor is not implemented; i.e., these rates are unobservable. In this section, we use ex-ante free-market rates as proxy outcomes for the future, counterfactual, free-market rates. The assumption behind these proxy rates is that future market shocks are zero in expected value. If that is not the case, policymakers can always adjust their forecasts accordingly.

The threshold also depends on a conjecture for the supply elasticity. Fig. 2 shows the share of product-routes for which we predict a reduction in quantities, depending on conjectures for the supply elasticity. In our application, policymakers should conjecture an elastic supply because most carriers are not tied to intermediaries or routes by long-term contracts. For an elastic supply, we predict a reduction in shipped tonnage for at least 58% of the product-routes. In Section 7, we estimate a supply elasticity of 1.7. Using that elasticity, policymakers could have predicted a reduction in shipped tonnage for 63% of the product-routes.

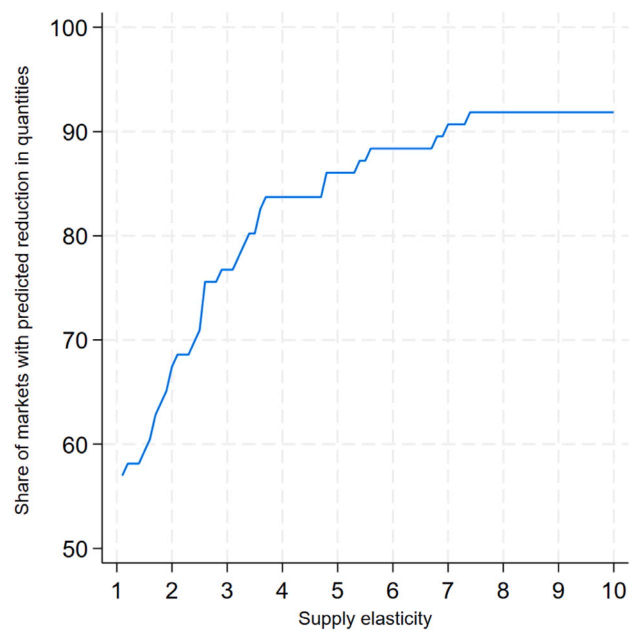


Fig. 2. Share of markets with a predicted reduction in quantities.
Our sample of markets are product-routes for which the price floor, ex-ante, was binding. We predict a reduction in tonnage shipped if the price floor enacted in 2016/08 is larger than the threshold of Proposition 3. We use ex-ante free-market prices as proxy outcomes for the future, counterfactual, free-market prices that appear in the formula for the threshold. In particular, we use average upstream freight rates at the product-route level, from 2015/08 to 2016/07–one year before the enactment of the price floor.

6. Effect on prices and quantities

We now estimate, ex-post, the average treatment effect of price floors on quantities. Our variables of interest are average freight rates per ton paid by intermediaries to carriers (upstream prices) and total tonnage shipped (quantities), both at the product-route level.

We first address the following counterfactual: what would have been the equilibrium prices and quantities in absence of the price floor? We implement both a difference-in-difference strategy and a triple difference strategy.

The difference-in-difference strategy exploits the heterogeneity in transport costs across products. For example, transporting electronics

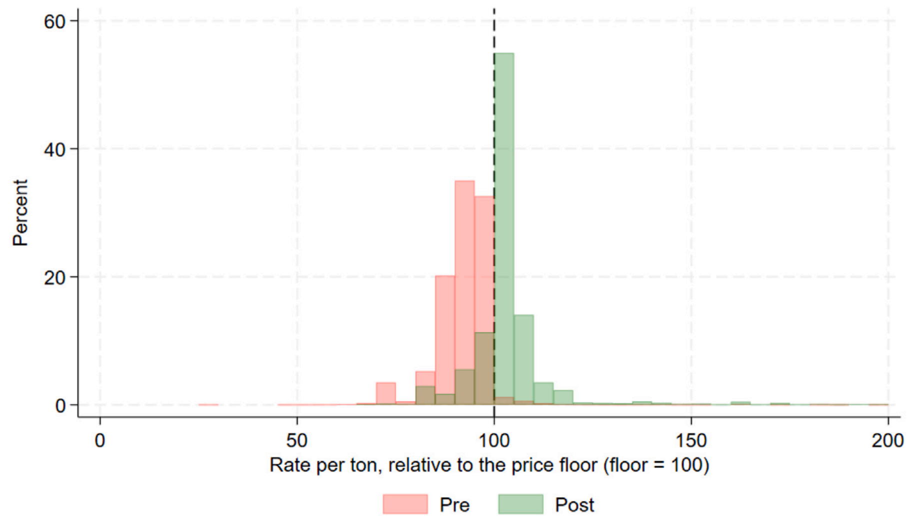


Fig. 3. Distribution of freight rates in the treatment group, relative to price floors.
Rate per ton at the trip level, relative to the price floor; i.e., $x = 100 * \text{Price}_{i,j,t}/\text{Price floor}_{j,t=post}$. The dotted line represents prices at exactly the level of the price floor. The pre-period comprises one year before the enactment of price floors. The post-period comprises one year following the enactment of price floors. The histogram is truncated at $x = 200$.

requires further security, monitoring, truck quality, and driver training than transporting toilet paper. Hence, freight rates are higher for some products than for others. In contrast, price floors were flat across products transported in the same route. In consequence, freight rate floors were binding for some products but not for others.

All rate floors were enacted at the same time, in August 2016. Our treatment group consists of products for which 95% of trips had rates below the floor through August 2014–July 2016, before floors were enacted.[20] Our control group consists of products for which 95% of trips had rates above the floor in the same period. The remaining products are not used in the analysis. Even after the floors were enacted, 22% of trips in the treatment group were priced below the floor. For the remaining trips, the intermediaries did not risk an audit; 54% of trips bunched within 5% above the price floor (Fig. 3).

We use two definitions for our treatment variable: binary and continuous. The binary variable, Treated $\text{product}_{i,j}$, takes the value of one if product i belongs to the treatment group for route j and zero otherwise. When the treatment is binary, we estimate the following model for the total tonnage of product i, in intervened route j, at time t, using ordinary least squares:

$$ln(\text{Q}_{i,j,t}) = \beta\,[\mathbb{1}(t \geq \text{August 2016}) \times \text{Treated product}_{i,j}] + \gamma_{ij} + \gamma_t + u_{i,j,t} \quad (7)$$

In our main specification, we define time periods by years, instead of months, because shipments at the product-route level are highly seasonal. Nevertheless, we also present results at the quarterly frequency.

Our estimator for β in Eq. (7) is a two-way fixed effects estimator of the average treatment effect on the treated (ATT). It is unbiased if the parallel trends assumption holds: that the control group and the treatment group would have had parallel trends if the treatment had not occurred. The parallel trends suffice for unbiasedness, even when treatment effects are heterogeneous, because (i) the treatment is binary, (ii) all treated products start receiving the treatment on the same period, and (iii) the treatment does not change intensity during our sample period (de Chaisemartin and D'Haultfoeuille, 2021, p. 4). Pre-trends for average rates and quantities are similar for both the treatment and control groups, which is consistent with the parallel trends assumption (Fig. 4).

Nevertheless, we consider a potential violation of the assumption: different supply shocks across product groups in the post-treatment period.[21] We explore this possibility with an alternative triple difference approach. We find a set of control routes in which price floors were not enacted but had the same origins and 90%–110% of the travel times of the treated routes. Next, we assign products in the control routes to the same treatment and control groups as in the intervened routes, even though there are no price floors in the control routes. In this sense, the treatment products in the control route are a placebo for the treatment products in the intervened route. We estimate the following triple-difference specification for product category i, in route j, at time t:

$$\begin{aligned} ln(\text{Q}_{i,j,t}) = {} & \beta_1 \text{ Treated product}_{i,j} \times \mathbb{1}(t \geq \text{August 2016}) \\ & + \beta_2 \text{ Treated route}_{i,j} \times \mathbb{1}(t \geq \text{August 2016}) \\ & + \beta_3 \text{ Treated product}_{i,j} \times \text{Treated route}_{i,j} \times \mathbb{1}(t \geq \text{August 2016}) \\ & + \gamma_{ij} + \gamma_t + u_{i,j,t} \end{aligned} \quad (8)$$

Another concern for the double-difference specification may arise if trucks switch from shipping treatment products to shipping control products in response to price floors. This equilibrium effect can be decomposed in two parts. The reduction in shipments in the treatment group is part of what we want to measure. The increase in shipments in the control group would create a downward bias on our estimators of the ATT on quantities. However, most products are neither in the control nor the treatment groups but in a third category excluded from the analysis, so this third category is likely to absorb most of the potential increase in shipments. In any case, this concern is also handled by our triple-difference specification.

Table 2 presents results for the double and triple difference strategies. We find that price floors increased prices and decreased quantities, as we had predicted in Section 5. Since both strategies provide similar estimates, we only report double-difference estimates from this point onwards.

Fig. 5 is an event-study plot that generalizes the double-difference estimates from Table 2 by: (i) using quarterly data instead of yearly

[20] Results are similar when we use 75% as a threshold in the group assignment, as we show in the appendix. Table A.8, in the appendix, lists the product categories included in the treatment group for each route.

[21] Suppose that the variable of interest is shipped tonnage. If the inputs for products in the treatment group became cheaper at the same time as the price floors were enacted, our estimator for β would be biased upwards.

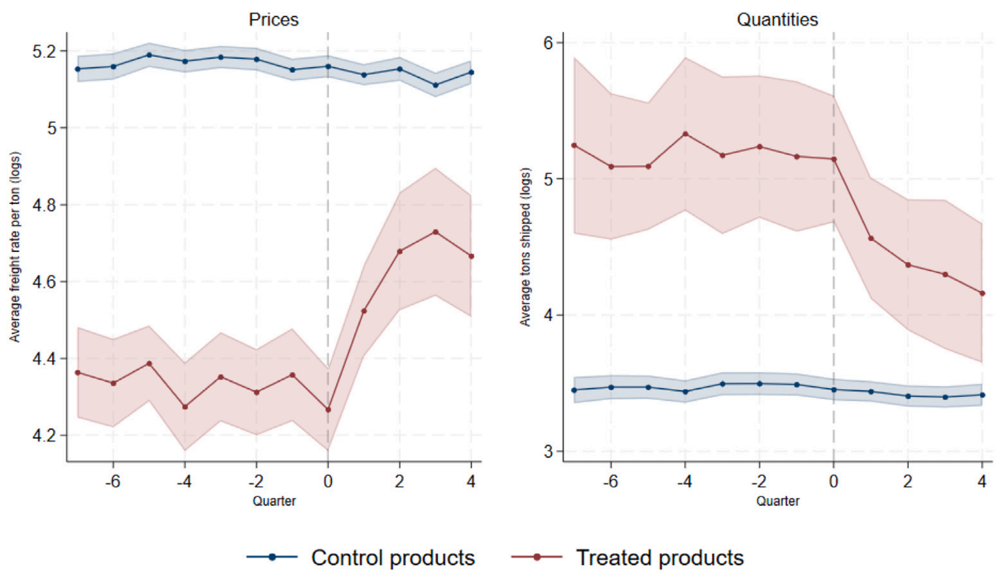


Fig. 4. Average freight rates and tonnage across product-routes.
Average across products for all routes with price floors. Price floors were implemented at the start of period 1. 95% confidence intervals.

Table 2
Effect on prices and quantities. Double and triple difference. Binary treatment.

	Price (logs)	Tons (logs)
Treated product × Time	0.41***	−0.47***
	(0.05)	(0.17)
Treated product × Intervened route × Time	0.40***	−0.51***
	(0.05)	(0.18)

Each cell refers to a different regression. The first row refers to β in Eq. (7), the double difference specification. The second row refers to β_3 in Eq. (8), the triple difference specification. Unit of observation is route-year-product. The pre-period comprises one year before the enactment of price floors. The post-period comprises one year following the enactment of price floors. The number of observations in the double and triple difference specifications are 4214 and 14,700, respectively. Standard errors in parentheses, clustered at route level. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 3
Effect on prices and quantities. Double difference. Continuous treatment.

	Price (logs)	Tons (logs)
Two way fixed effects	2.07***	−1.91*
	(0.44)	(1.13)
DID_M	3.06***	−3.52**
	(0.41)	(1.50)

Each cell refers to a different regression. The first row refers to β in the continuous version of Eq. (7), the two-way fixed effect estimator, which is biased. The second row refers to the DID_M estimator proposed by de Chaisemartin and D'Haultfoeuille (2020), which is unbiased under the parallel trends assumption. In both cases the continuous treatment is defined as in Eq. (9). The unit of observation is route-year-product. The pre-period comprises one year before the enactment of price floors. The post-period comprises one year following the enactment of price floors. The number of observations in both specifications is 4214. The average of the continuous treatment variable at the route-product level is 0.13. Standard errors in parentheses, clustered at route level. For the DID_M estimator, standard errors are obtained through a bootstrap of 10,000 iterations. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

data (ii) extending the pre-enactment period to two years instead of one, and (iii) interacting the treatment with quarterly indicators. While this approach introduces seasonality, it enhances our comprehension of the underlying dynamics. We find that the effect of price floors on prices and quantities did not exhibit a reversal during the initial year of implementing the price floors.

We supplement our analysis with a continuous treatment variable that measures the level of the rate floor, relative to pre-treatment freight rates. Let TG be the set of product-routes in the treatment group. The continuous treatment for product i, in route j, at time t is:

$$\text{Treatment}_{i,j,t} = \begin{cases} \sum_{\text{shipments in } i,j,t\le 0} \frac{ln(\text{Floor}_{j,t}) - ln(\text{Rate}_{shipment})}{\text{Number of trips}_{i,j,t\le 0}} & \text{if } (i,j)\in TG \text{ and } t>0 \\ 0 & \text{Otherwise} \end{cases} \quad (9)$$

When the treatment is continuous and treatment effects are heterogeneous, we have two considerations. First, there are two treatment effects of potential interest. The average treatment effect on the treated (ATT) is an average of level effects: the average effect of being treated with a particular price floor instead of not being treated at all. In contrast, the average causal response on the treated (ACRT) is an average of slope effects: the average effect of increasing price floors across treated products. Parallel trends suffice to identify the ATT but not to identify the ACRT (Callaway et al., 2021). Propositions 1–4 from our theoretical model are based on a level comparison: a market with price floors versus a free market. Hence, estimating the ATT suffices for the purposes of this paper.

A second consideration for the continuous treatment is that the two-way fixed effect estimator might be biased under heterogeneous effects. Consequently, we implement the DID_M estimator by de Chaisemartin and D'Haultfoeuille (2020), which is unbiased under the parallel trends assumption.

Table 3 compares these unbiased estimates with the biased estimates from using two-way fixed effects. Overall, rate floors induced large reductions in shipped tonnage for the routes and products for which rate floors were binding: between 37% and 40% on average, depending on the estimator.[22]

This reduction in total tonnage did not occur through a reduction in the number of trips (Fig. A.9 and Tables A.9 and A.10 in the Appendix). Rather, it occurred through a reduction in tonnage per trip: trucks were smaller or emptier. This result suggests an increase in carbon emissions per ton transported that could have been an additional unintended effect of the policy in Colombia.

[22] Double difference, binary: $e^{-0.47} - 1 \approx -37\%$. Triple difference, binary: $e^{-0.51} - 1 \approx -40\%$. DID_M estimator multiplied by the average continuous treatment among the treated: $e^{-3.52\times 0.13} - 1 \approx -37\%$.

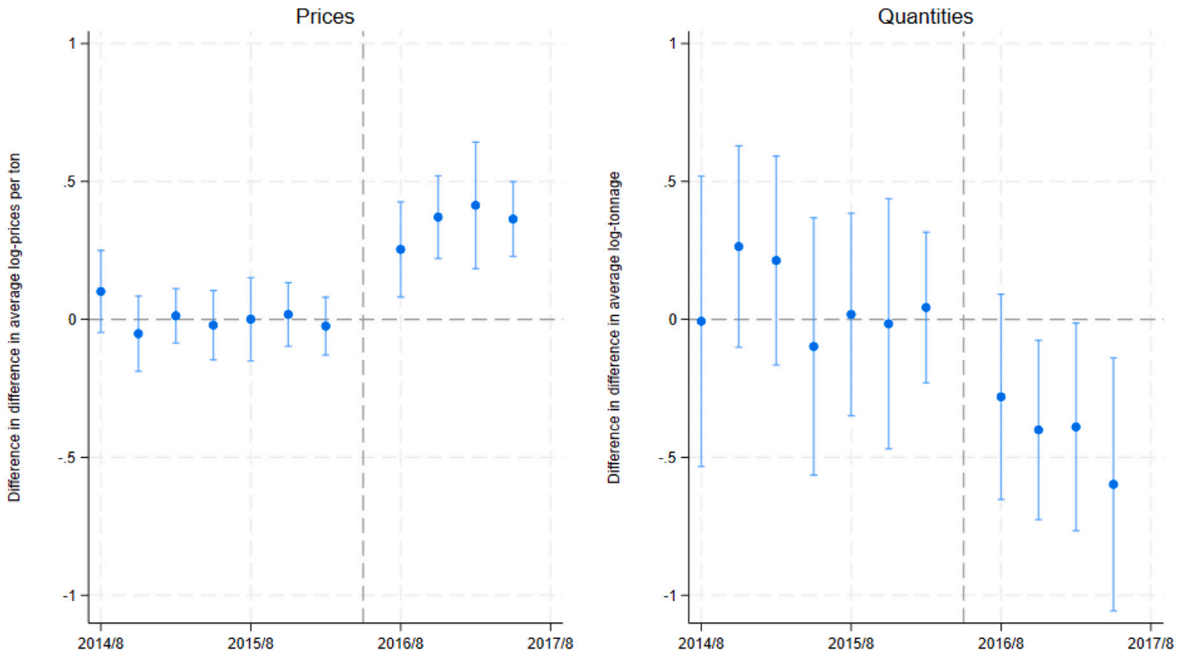


Fig. 5. Event study on freight rates and tonnage.
The estimated equation is $ln(Q_{i,j,t}) = \sum_{t' \neq 0} \beta_{t'} [\mathbb{1}(t = t') \times \text{Treated product}_{i,j}] + \gamma_t + \gamma_{ij} + u_{i,j,t}$. Each point is the difference in difference coefficient for treatment vs. control in each quarter. The base quarter is 2016/5 - 2016/7, the last free market quarter. The unit of observation is route-quarter-product level. Confidence intervals at the 95% level with standard errors clustered at route level.

Table 4
Effect on quantities interacted with number of intermediaries. Double difference. Binary treatment.

	f(·) = n			f(·) = log(n)			f(·) = HHI		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Treated product × Time × f(·)	−0.01	−0.03	0.09	−0.08	0.54*	0.56	−0.14	1.09	5.98
	(0.01)	(0.04)	(0.06)	(0.20)	(0.30)	(0.68)	(0.66)	(1.76)	(6.94)
Treated product × Time × f(·)^2		0.00	−0.01*		−0.15*	−0.21		−1.12	−13.36
		(0.00)	(0.00)		(0.08)	(0.36)		(1.43)	(15.73)
Treated product × Time × f(·)^3			0.00*			0.02			8.00
			(0.00)			(0.05)			(9.94)
Remaining interactions with function of intermediaries	X	X	X	X	X	X	X	X	X
Remaining terms of the dif-in-dif specification	X	X	X	X	X	X	X	X	X
Route FE	X	X	X	X	X	X	X	X	X
N	4249	4249	4249	4249	4249	4249	4249	4249	4249
Adjusted R^2	0.06	0.07	0.07	0.07	0.07	0.07	0.06	0.06	0.06

We estimate an extension of Eq. (7) by adding interactions with polynomials of the number of intermediaries, the log-number of intermediaries, or the Herfindahl–Hirschman index. Unit of observation is route-year-product. The pre-period comprises one year before the enactment of price floors. The post-period comprises one year following the enactment of price floors. In contrast to the previous tables, we do not include route-product fixed effects because n is constant over time. Standard errors in parentheses, clustered at route level. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

We now explain the reduction in quantities by testing whether the intervened markets were approximately competitive, based on Proposition 4. In particular, Table 4 extends this proposition by including interactions with polynomials of the number of intermediaries, the log-number of intermediaries, or the Herfindahl–Hirschman index. In most specifications, coefficients are small and statistically non-significant, suggesting that intermediaries behave in a competitive manner for most product-routes.

In summary, rate floors reduced efficiency through a reduction in tonnage for the treated products. Tonnage fell on average because intermediation markets are approximately competitive in most product-routes. The ex-ante predictions of Section 5, which were based on Proposition 3, were correct: the rate floors were set too high.

7. Estimation of elasticities of supply and demand

Proposition 6 provides a formula for a lower bound on the supply elasticity. The bound depends on the number of intermediaries (n) and the effect of the price floor on upstream prices (W^{PF}/W^{FM}), which we estimated in Section 6. The estimates for the lower bound are low in our application, with a mean of 0.77 and a median of 0.28 across product-routes. The estimated bounds are low because most markets have many intermediaries, so a reduction in quantities can occur even with low elasticities of supply.

Consequently, we use an alternative approach to point-estimate the elasticity of supply. Between May 16 and June 6, 2017, protesters blocked the second largest port in Colombia, Buenaventura (Jaramillo Marín et al., 2020). Cargo accumulated in the port for three weeks, as few outbound trips were able to leave the port. Once the protests ended, the demand for outbound trips was artificially high while the accumulated cargo was evacuated. Consistent with a rightward shift in demand for transportation, both freight rates and shipped tonnage were higher right after the protests than before the protests (Fig. 6).

We use a dif-in-dif strategy to estimate the supply elasticity. We first estimate the effect of the demand shift on average freight rates and

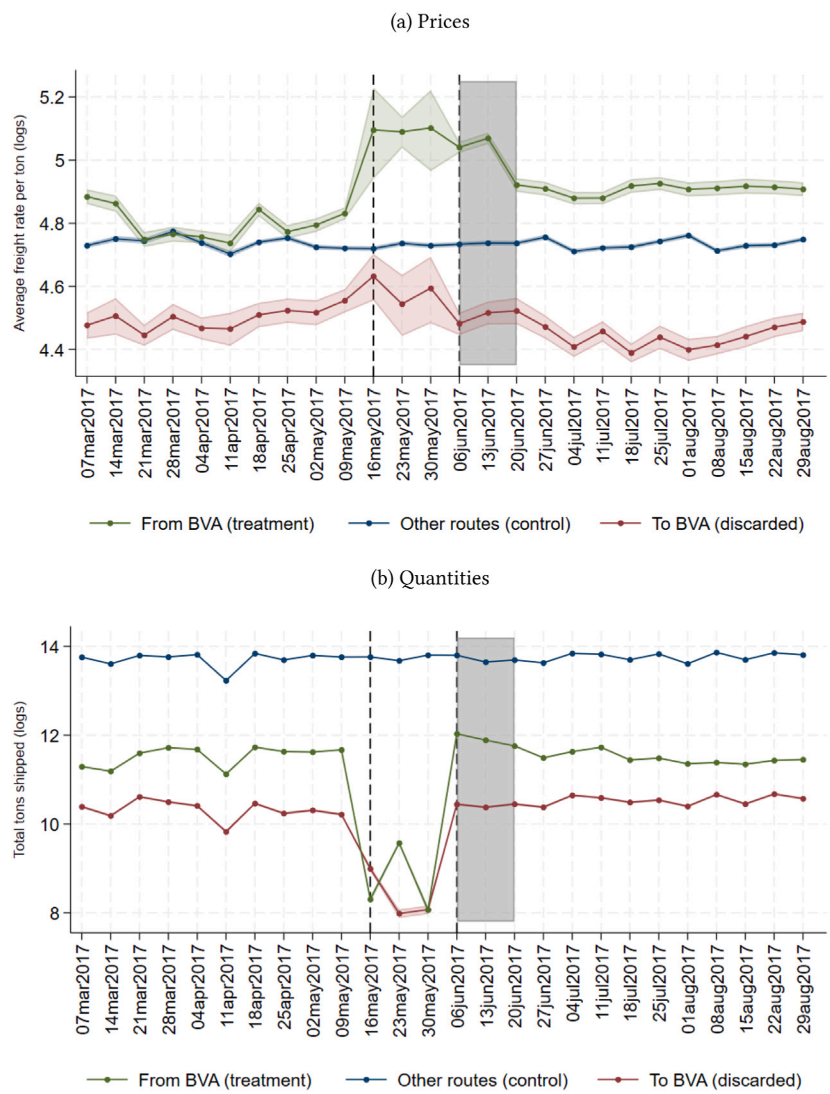


Fig. 6. Demand shift after the protests in Buenaventura.
Weekly data. The vertical lines are the start and end of the protests, when few outbound trips were able to leave the port. The shaded area is the treatment period, when increased inventories within the port shifted the demand for transportation to the right, increasing prices and quantities relative to the period before the protests.

total tonnage (in logs). Our treatment group consists of product-routes leaving Buenaventura. Our control group consists of product-routes with origins and destinations other than Buenaventura. We discard routes that arrive to Buenaventura. Following the price pattern in Fig. 6, our treatment time covers the first two weeks after the end of the protests. We discard the weeks in which the protests occurred. We estimate two specifications. We model the total tonnage for group j in day d as:

$$ln(Q_{j,d}) = \beta_0 + \beta_1 \text{Treatment group}_j + \beta_2 \text{Treatment time}_d + \beta_3 \text{Treatment group}_j \times \text{Treatment time}_d + \gamma_{\text{day of week}_d} + u_{j,d} \quad (10)$$

Alternatively, we model the total tonnage for product i and route j in week w as:

$$ln(Q_{i,j,w}) = \beta_0 + \beta_2 \text{Treat time}_w + \beta_3 \text{Treat group}_j \times \text{Treat time}_w + \gamma_{ij} + u_{i,j,w} \quad (11)$$

The supply elasticity is the ratio of estimates of β_3 for quantities and prices. We report estimates for both specifications, with similar results, in Table 5. Since the product-route estimate has lower standard errors, we use $\epsilon^s = 1.70$ from this point onward.

Table 5
Supply elasticity: point-estimates.

	Effect on price	Effect on quantities	Supply elasticity
Aggregate level	0.24	0.38	1.59
	(0.03)	(0.19)	(0.77)
Product-route level	0.14	0.24	1.70
	(0.02)	(0.03)	(0.19)

The pre-period comprises one month before the enactment of price floors. The post-period comprises two weeks following the enactment of price floors. The aggregate level refers to Eq. (10) estimated at the daily level, with 44 observations and standard errors robust to heteroskedasticity. The product-route level refers to Eq. (11) estimated at the product-route-week level, with 62,280 observations and standard errors clustered by route. For the elasticities, we report the standard errors of a 2SLS procedure regressing log-quantities on instrumented log-prices, with log-prices instrumented as in Eqs. (10) and (11). We thank a referee for suggesting this procedure.

Given $\epsilon^s = 1.70$, we can verify whether the price floors for each product-route are higher, ex-post, than the threshold of Proposition 3.

Table 6
Demand Elasticity: point-estimates.

	n→ ∞	n finite					
		p10	p25	p50	p75	p90	mean
Dif-in-Dif, Binary	1.15 (0.41)	1.20	1.25	1.31	1.49	2.05	1.49
Dif-in-Dif, Continuous, DID_M	1.15 (0.62)	1.21	1.26	1.37	1.72	2.79	1.83
Dif-in-Dif-in-Dif, Binary	1.24 (0.44)	1.31	1.36	1.42	1.63	2.25	1.62

We calculate the demand elasticity by using Proposition 5 and the supply elasticity of 1.7 taken from Table 5. When $n \to \infty$, the estimate is unique across product-routes by construction. When $n \to \infty$ and the treatment is binary, we report the standard errors of a 2SLS procedure regressing log-quantities on instrumented log-prices, with log-prices instrumented as in Eqs. (7) and (8). We thank a referee for suggesting this procedure. When $n \to \infty$ and the treatment is continuous, we use bootstrapping with 10,000 replications to obtain the standard errors. In both cases, standard errors are clustered by route. When n is finite, we present descriptive statistics of the distribution of demand elasticities across product-markets. We cannot estimate demand elasticities for the 13% of product-routes for which the model, ex-post, implies tonnage increases as this result contradicts the negative average effect on tonnage that we are using in the numerator of the formula for elasticities (Tables 2 and 3).

This is the case for 87% of product-routes in the treatment group: ex-post, the theoretical model would imply tonnage reductions among these product-routes. For the remaining 13% of product-routes, the model would imply tonnage increases due to market power in their intermediation markets.

We estimate the elasticity of demand by using Proposition 5. If the intermediation market is approximately competitive, as we found in Table 4, the formula simplifies to the ratio between the effect of price floors on log-quantities and the effect of price floors on log-prices. In that case, the estimated elasticity is homogeneous across product-routes: 1.15 (Table 6).

In the general case that allows for market power, our estimator depends on the supply elasticity, the number of intermediaries and the treatment intensity. Hence, the estimated elasticity differs across product-routes. In Table 6, we report descriptive statistics of the distribution of demand elasticities across product-routes. For at least 10% of the product-routes, the demand elasticity is greater than 2. Hence, perfect-competition does not provide a good approximation for estimating the demand of this 10% of product-routes.

8. Incidence

We study the redistribution of welfare between sellers, intermediaries, and buyers that followed from the enactment of price floors. We provide two sets of incidence calculations: (i) allowing for market power by intermediaries (n finite), and (ii) using $n \to \infty$ as a perfectly competitive approximation that is consistent with most specifications in Table 4. Our partial equilibrium calculation is standard, as in Fig. 7. We perform the calculations of Fig. 7 for each product-route in the treatment group. Next, we sum over product-routes. We explain the details of our procedure in Appendix A.3.

Table 7 reports our calculations. As a result of price floors, shippers of treated products lost 26% of market revenue, defined as the dot product of shipped tonnage and upstream freight rates under a (counter-factual) free market. Intermediaries lost 6% of market revenue. Carriers gained 20% of market revenue. Overall, the deadweight loss from price floors was 12% of market revenue.

The estimated loss of 6% of market revenue by intermediaries implies that the intermediation market was oligopolic for a subset of product-routes. Nevertheless, two results suggest that perfect competition is a good approximation for most routes: (i) 90% of the redistributive gains to carriers come from shippers, not intermediaries; and (ii) net gains for shippers and carriers are similar under the general case and under the competitive approximation. This result suggests that the perfect-competition test from Table 4 was correct for most routes.

9. Conclusions

This paper shows how to predict, estimate, and explain the effect of price floors on output and the distribution of welfare in markets with intermediaries. We provide a toolkit that consists of: (i) a rule to predict, ex-ante, whether a price floor will reduce the equilibrium quantity in a given market; (ii) a test to evaluate, ex-post, whether a price floor reduced equilibrium quantities on average across markets; (iii) a test that uses price floors to evaluate whether markets are competitive; and (iv) estimators for demand and supply elasticities that are contingent upon variations in price floors. We use these elasticities to estimate the incidence of price floors. Our method can be used by scholars and policy makers with limited resources, data, and time—it is a substantial improvement over the current practice by policymakers, which is extrapolating past prices or accounting costs to set price floors.

Colombian policymakers implemented price floors in the Colombian road freight sector in 2016. If our toolkit had been available at the time, policymakers could have predicted that price floors would reduce quantities – and hence, efficiency – in most routes. Indeed, once the price floors were enacted, quantities fell 37% on average for the routes and products for which the price floors were binding. Quantities fell because the intermediation market for most of those routes was competitive at the time. Spain enacted rate floors in the road freight sector in August 2022.[23] Spanish policymakers could use our toolkit to prevent reductions in intranational trade.

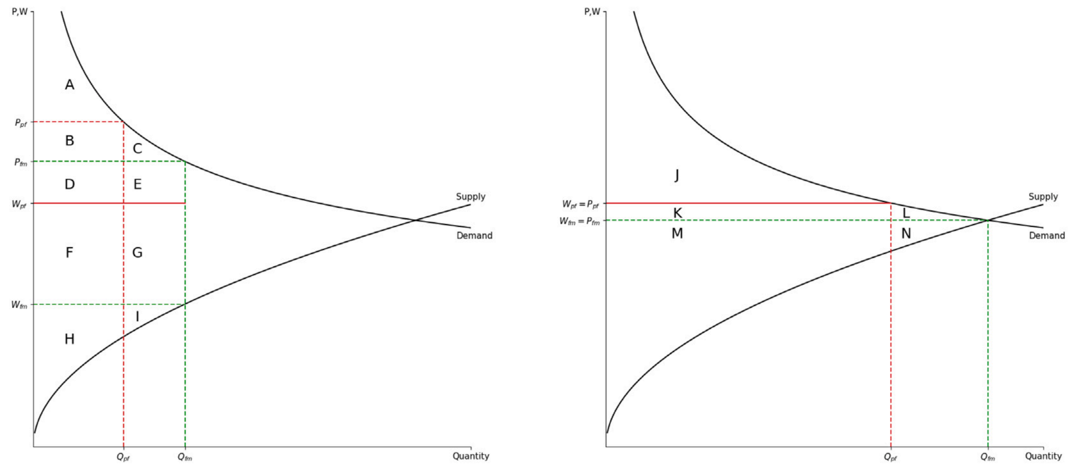
Across product-routes, we estimate a median elasticity of demand of 1.4 and a supply elasticity of 1.7. We use our estimated distribution of elasticities to estimate the incidence of the freight rate floors implemented in 2016. Floors created losses for shippers and intermediaries that were 61% larger than the gains for carriers. Overall, the deadweight loss from floors was 12% of market revenue.

On efficiency grounds, the enactment of freight rate floors was not justified in our empirical application. However, redistribution was equally important from the point of view of policy makers: as it happened, price floors were motivated by a carriers' strike. Policy makers can use our estimated elasticities and incidence calculations to design public policies as redistributive and politically feasible as price floors but more efficient.

Declaration of competing interest

None

[23] Article 1, Chapter 1, Royal Decree-Law 14 of 2022.



(a) Market power (n finite)

(b) Perfect competition ($n \to \infty$)

Fig. 7. Incidence in partial equilibrium.
We study a price floor that reduces quantities from Q_{FM} to Q_{PF}. In sub Fig. 7(a), we allow for market power among intermediaries. As a result of the price floor, there is welfare redistribution from shippers to intermediaries (B) and from intermediaries to carriers (F). In addition, a reduction in quantities reduces welfare for shippers, intermediaries and carriers: C, $E+G$, and I, respectively. Deadweight loss from the price floor is therefore $C+E+G+I$. In sub Fig. 7(b), the intermediation sector is perfectly competitive, so the economic profits of intermediaries are always zero. Redistribution from shippers to carriers is K. Shippers and carriers lose L and N, respectively, due to the reduction in shipped quantities. Deadweight loss from the price floor is $L+N$. We explain the details of our procedure to calculate each area in Appendix A.3 of the Appendix.

Table 7
Incidence of price floors, as a share of free-market revenue.

n finite

	Δ Welfare due to redistribution	Δ Welfare due to fall in quantities	Net gain
Shippers	−20.5	−5.5	−25.9
Intermediaries	−2.2	−3.9	−6.1
Carriers	22.7	−2.8	19.9
Total	0.0	−12.1	−12.1

$n \to \infty$

	Δ Welfare due to redistribution	Δ Welfare due to fall in quantities	Net gain
Shippers	−22.7	−5.6	−28.3
Intermediaries	0.0	0.0	0.0
Carriers	22.7	−2.8	19.9
Total	0.0	−8.4	−8.4

Welfare calculations for the 87% of treated product-routes with estimated demand elasticities (Table 6). Market revenue is the dot product of shipped tonnage and upstream freight rates under a (counter-factual) free market. The formulas to calculate each item are in Appendix A.3 of the Appendix. The formulas depend on the elasticities of supply and demand. We take the former from Table 5 ($\epsilon^s = 1.7$) and the latter from using Proposition 5 and the continuous treatment for each product-route (see Table 6 for summary statistics).

Data availability

Processed data available for replication upon request. Raw data is confidential, requiring Colombian Ministry of Transport's permission.

Appendix A

A.1. Proof of Proposition 1

We first show that, in any equilibrium, $Q = Q^s\left(W^{PF}\right)$. Next, we construct an equilibrium. We finish our proof by constructing another equilibrium with the same aggregate output but different aggregate costs.

Let:

$$\pi_i^B(q_i; q_-, W^{PF}) = \left[P(Q) - W^{PF} - c_i\right] q_i$$

$$\pi_i^{NB}(q_i; q_-) = \left[P(Q) - W(Q) - c_i\right] q_i$$

$$\pi_i(q_i; q_-, W^{PF}) = \max_{q_i} \begin{cases} \pi_i^B(q_i; q_-, W^{PF}) & \text{if } Q \leq Q^s(W^{PF}) \\ \pi_i^{NB}(q_i; q_-) & \text{if } Q > Q^s(W^{PF}) \end{cases}$$

$$\hat{W} : P\left(Q^s\left(\hat{W}\right)\right)\left(1 - \frac{1}{n\epsilon^d}\right) = \hat{W} + \bar{c}$$

$$W^{PF} : W^{FM} < W^{PF} < \hat{W}$$

Lemma A.1. *In any equilibrium, $W = W^{PF}$ and $Q = Q^s\left(W^{PF}\right)$.*

Proof. Suppose not. Then $W = W^* > W^{PF}$ and $Q = Q(W^*) > Q^s\left(W^{PF}\right)$ in equilibrium, so:

$$0 = P\left(Q^s\left(W^*\right)\right)\left(1 - \frac{1}{n\epsilon^d}\right) - W\left(Q^s\left(W^*\right)\right)\left(1 + \frac{1}{n\epsilon^s}\right) - \bar{c}$$

(First order conditions, averaged)

$$< P\left(Q^s\left(W^{FM}\right)\right)\left(1 - \frac{1}{n\epsilon^d}\right) - W\left(Q^s\left(W^{FM}\right)\right)\left(1 + \frac{1}{n\epsilon^s}\right) - \bar{c}$$

$$(W^{FM} < W^{PF} < W^*)$$
$$= 0$$
(Equation (2))

which is a contradiction. □

Lemma A.2. *In any equilibrium, there exists at least one intermediary i such that $\frac{\partial \pi_i^B(q_i; q_{-}, W^{PF})}{\partial q_i} > 0$.*

Proof. Suppose not. Then $Q = Q^s\left(W^{PF}\right)$ and $\frac{\partial \pi_i^B(q_i; q_{-}, W^{PF})}{\partial q_i} = 0\ \forall\ i$. Then,

$$\begin{aligned}0 &= P\left(Q^s\left(W^{PF}\right)\right)\left(1-\frac{1}{n\epsilon^d}\right) - W^{PF} - \bar{c} && \text{(First order conditions, averaged)}\\ &> P\left(Q^s\left(\hat{W}\right)\right)\left(1-\frac{1}{n\epsilon^d}\right) - \hat{W} - \bar{c} && (W^{PF} < \hat{W})\\ &= 0 && \text{(Definition of } \hat{W})\end{aligned}$$

which is a contradiction. □

Lemma A.3. *There exists at least an equilibrium.*

Proof. We construct such equilibrium. Let $q^\dagger = \{q_1^\dagger, \dots, q_N^\dagger\}$ satisfy $\frac{\partial \pi_i^B(q_i; q_{-}, W^{PF})}{\partial q_i} = 0\ \forall\ i$. Let $Q^\dagger = \sum_{i=1}^n q_i^\dagger$. By the second order condition, $Q^\dagger > Q^s\left(W^{PF}\right)$. Let $\gamma = \frac{Q^s\left(W^{PF}\right)}{Q^\dagger} < 1$. Let $q^* = \gamma q^\dagger$, so $\sum_{i=1}^n q_i^* = Q^s\left(W^{PF}\right)$. Then $\frac{\partial \pi_i^B(q_i^*; q_{-}, W^{PF})}{\partial q_i} > 0\ \forall\ i$ because quantities are strategic substitutes in a Cournot game and because of the second order condition (marginal profits decreasing in q). Hence, no intermediary has incentives to deviate from q^* by reducing quantities. No intermediary has incentives to increase quantities either: an increase in quantities would increase prices above the price floor, which implies a discontinuous increase in total cost accompanied by a continuous increase in total revenue, which in turn implies a reduction in profits. Hence, $\{q_1^*, \dots, q_N^*; W^{PF}, P^{PF}\}$ is an equilibrium. □

Lemma A.4. *There are multiple equilibria if $n > 1$.*

Proof. We construct a new equilibrium from a given equilibrium. Let $\{q_1^*, \dots, q_N^*; W^{PF}, P^{PF}\}$ be an equilibrium. Then $\frac{\partial \pi_i^B(q_i^*; q_{-}, W^{PF})}{\partial q_i} > 0$ for some i (Lemma A.2). Consider intermediary $j \neq i$ such that $q_j^* > 0$. Because of continuity, there exists ϵ such that $0 < \epsilon < q_j^*$, $\frac{\partial \pi_i^B(q_i^*+\epsilon; \cdot)}{\partial q_i} > 0$, and $\frac{\partial \pi_i^B(q_j^*-\epsilon; \cdot)}{\partial q_j} > 0$. Then $\{q_1^*, \dots, q_i^* + \epsilon, q_j^* - \epsilon, \dots, q_N^*; W^{PF}, P^{PF}\}$ is an equilibrium as well. □

Remark. If $c_i > c_j$, then $\{q_1^*, \dots, q_N^*; W^{PF}, P^{PF}\}$ is more efficient than $\left\{q_1^*, \dots, q_i^* + \epsilon, q_j^* - \epsilon, \dots, q_N^*; W^{PF}, P^{PF}\right\}$.

A.2. Proof of Proposition 4

First, we find the upstream price under a free market. In equilibrium, $Q^d = Q^s$. Hence, $k^d P^{-\epsilon^d} = k^s W^{\epsilon^s}$. Replace P^{FM} from Eq. (3) to obtain:

$$W^{FM} = \left(\frac{k^d}{k^s}\right)^{\frac{1}{\epsilon^s+\epsilon^d}} \left(\frac{1-\frac{1}{n\epsilon^d}}{1+\frac{1}{n\epsilon^s}}\right)^{\frac{\epsilon^d}{\epsilon^s+\epsilon^d}} \tag{A.1}$$

Replace equation (A.1) in Eq. (6) to obtain:

$$\frac{Q^{PF}}{Q^{FM}} = \left[\frac{1}{W^{PF}}\left(\frac{k^d}{k^s}\right)^{\frac{1}{\epsilon^s+\epsilon^d}}\right]^{\epsilon^d} \left[\left(1+\frac{1}{n\epsilon^s}\right)^{\frac{\epsilon^s}{\epsilon^s+\epsilon^d}}\left(1-\frac{1}{n\epsilon^d}\right)^{\frac{\epsilon^d}{\epsilon^s+\epsilon^d}}\right]^{\epsilon^d}$$

So:

$$\frac{\mathrm{d}Q^{PF}/Q^{FM}}{\mathrm{d}n} = \left[\frac{1}{W^{PF}}\left(\frac{k^d}{k^s}\right)^{\frac{1}{\epsilon^s+\epsilon^d}}\right]^{\epsilon^d} \left[\left(1+\frac{1}{n\epsilon^s}\right)^{\frac{\epsilon^s}{\epsilon^s+\epsilon^d}}\left(1-\frac{1}{n\epsilon^d}\right)^{\frac{\epsilon^d}{\epsilon^s+\epsilon^d}}\right]^{\epsilon^d} \frac{\epsilon^d}{n(n\epsilon^s+1)(n\epsilon^d-1)} \tag{A.2}$$

As long as $\epsilon^d > 1/n$, all terms in Eq. (A.2) are positive. Hence, $\frac{\mathrm{d}Q^{PF}/Q^{FM}}{\mathrm{d}n} > 0$. In addition:

$$\lim_{n\to\infty} \frac{\mathrm{d}\left(Q^{PF}/Q^{FM}\right)}{\mathrm{d}n} = 0$$

A.3. Incidence calculations

We estimate welfare changes for sellers, intermediaries and buyers by estimating, for each product-route in the treatment group, the areas in Fig. 7. We allow demand and supply to shift across periods, i.e., we allow for $k^s_{FM} \neq k^s_{PF}$ and $k^d_{FM} \neq k^d_{PF}$. A first step is to obtain W_{FM}, P_{FM}, Q_{FM}, W_{PF}, P_{PF}, Q_{PF}, k^s_{FM}, k^s_{PF}, ϵ^s, k^d_{FM}, k^d_{PF}, and ϵ^d.

We observe the average W_{PF} and total Q_{PF} after the price floor was enacted. We backup the counterfactual W_{FM} and Q_{FM} using W_{PF}, Q_{PF}, and the DID_M-estimated effects from Section 6. We obtain the DID_M-estimated C and ϵ^d from Section 7.

We do not observe P_{FM} and P_{PF} in our data. We overcome this data limitation by solving P_{FM} and P_{PF} from Eqs. (3) and (5) from our theoretical model. While doing this step, we assume $\bar{c} = 0$ because $\bar{c}$ is not identified when P_{FM} and P_{PF} are not observed. Given W_{FM}, W_{PF}, P_{FM}, P_{PF}, ϵ^s, and ϵ^d, we can solve for k^s_{FM}, k^s_{PF}, k^d_{FM}, and k^d_{PF} using the supply and demand functions.

When the intermediation market is oligopolic, the welfare calculation follows Sub Fig. 7(a). Welfare redistribution from shippers to intermediaries is:

$$\text{Redistribution from S to I}_{i,j} = Q^{PF}_{i,j}\left(P^{PF}_{i,j} - P^{FM}_{i,j}\right) \tag{A.3}$$

Redistribution from intermediaries to carriers is:

$$\text{Redistribution from I to C}_{i,j} = Q^{PF}_{i,j}\left(W^{PF}_{i,j} - W^{FM}_{i,j}\right) \tag{A.4}$$

Welfare losses for shippers due to a reduction in shipped quantities for product i in route j are:

$$\begin{aligned}\text{Loss}^{shippers}_{i,j} \text{ due to} \downarrow Q_{i,j} &= \int_{P^{FM}_{i,j}}^{P^{PF}_{i,j}} k^d_{i,j} p^{-\epsilon^d}\, dp - \text{Redistribution from S to I}_{i,j}\\ &= \frac{P^{PF}_{i,j}Q^{PF}_{i,j} - P^{FM}_{i,j}Q^{FM}_{i,j}}{1-\epsilon^d} - \text{Redistribution from S to I}_{i,j}\end{aligned} \tag{A.5}$$

Welfare losses for intermediaries due to a reduction in shipped quantities for product i in route j are:

$$\text{Loss}^{intermediaries}_{i,j} \text{ due to} \downarrow Q_{i,j} = \left(P^{FM}_{i,j} - W^{FM}_{i,j}\right)\left(Q^{FM}_{i,j} - Q^{PF}_{i,j}\right) \tag{A.6}$$

Let $W(Q^{PF}_{i,j})$ be the value of the inverse supply function, evaluated at the observed equilibrium quantity under the price floor. Welfare losses for carriers due to a reduction in shipped quantities for the product i in route j are:

$$\begin{aligned}\text{Loss}^{carriers}_{i,j} \text{ due to} \downarrow Q_{i,j} &= W^{FM}_{i,j}\left(Q^{FM}_{i,j} - Q^{PF}_{i,j}\right) - \int_{Q^{PF}_{i,j}}^{Q^{FM}_{i,j}} \left(\frac{q}{k^s_{i,j}}\right)^{\frac{1}{\epsilon^s}} dq\\ &= W^{FM}_{i,j}\left(Q^{FM}_{i,j} - Q^{PF}_{i,j}\right)\\ &\quad - \frac{\epsilon^s}{1+\epsilon^s}\left(W^{FM}_{i,j}Q^{FM}_{i,j} - W(Q^{PF}_{i,j})Q^{PF}_{i,j}\right)\end{aligned} \tag{A.7}$$

Deadweight loss for product i in route j, $\text{Loss}_{i,j}$, is the sum of Eqs. (A.5), (A.6), and (A.7).

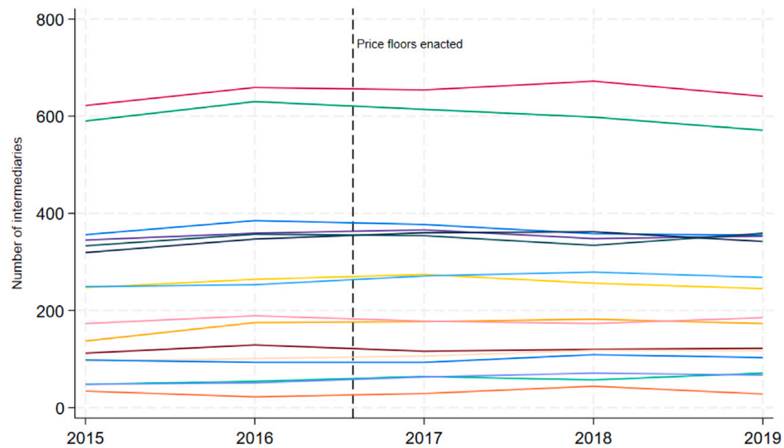


Fig. A.8. Number of intermediaries in intervened routes. Each line corresponds to an intervened route.

Table A.8
Harmonized System (HS) codes of treated products in each route.

Intervened routes	Products
Buenaventura – Cali	001001, 001008, 002520, 002523, 002608, 002616, 002820, 007204, 007224, 2674
Cucuta – Barranquilla	000901, 002519, 002617, 003105
Santa Marta – Bucaramanga	000210, 002306
Bogota – Cartagena	001504, 002704
Bogota – Cali	004402, 004706, 007006, 007224
Bogota – Buenaventura	001302, 001504, 002201, 002508, 002515, 002701, 003201, 003703, 003918, 004402, 007403, 008408
Medellin – Cartagena	001108, 004001, 006801, 007406, 007408, 1977, 2000
Manizales – Bogota	006902, 007217
Cali – Barranquilla	001503, 001703, 001902, 003407, 007007, 007207, 007214, 007801, 009406
Medellin – Barranquilla	001006, 002705, 004801, 006801, 009024, 1401
Manizales – Medellin	004006, 007002, 007016, 007214, 007217, 007218, 008209, 008433
Manizales – Buenaventura	002524, 007208
Bogota – Ipiales	003816, 004421, 005510, 006902, 006907, 007215, 007227
Manizales – Barranquilla	002524, 003923, 004006, 007002, 007206, 007214, 007228, 007326, 008209
Medellin – Buenaventura	002201, 002827, 003908, 005604, 007204
Buenaventura – Pitalito	000901, 001005, 002511, 003103, 003105, 006901

When the intermediation market is competitive, Eqs. (3) and (5) deliver $W = P$. Hence, the welfare calculation is as in Sub Fig. 7(b).

Redistribution from shippers to carriers is:

$$\text{Redistribution}_{i,j} = Q^{PF}_{i,j}\left(W^{PF}_{i,j} - W^{FM}_{i,j}\right) \tag{A.8}$$

Welfare losses for shippers due to a reduction in shipped quantities for product i in route j are:

$$\begin{aligned}\text{Loss}^{shippers}_{i,j} \text{ due to} \downarrow Q_{i,j} &= \int_{W^{FM}_{i,j}}^{W^{PF}_{i,j}} k^d_{i,j} p^{-\epsilon^d}\, dp - \text{Redistribution}_{i,j} \\ &= \frac{W^{PF}_{i,j}Q^{PF}_{i,j} - W^{FM}_{i,j}Q^{FM}_{i,j}}{1-\epsilon^d} - \text{Redistribution}_{i,j}\end{aligned} \tag{A.9}$$

The loss of surplus for carriers due to a reduction in shipped quantities for product i in route j is also calculated as in Eq. (A.7).

Deadweight loss for product i in route j, $\text{Loss}_{i,j}$, is the sum of Eqs. (A.7) and (A.9).

We define the aggregate loss in welfare as a share of market revenue as:

$$\text{Loss} = \frac{\sum_i \sum_j \text{Loss}_{i,j}}{\sum_i \sum_j W^{FM}_{i,j} Q^{FM}_{i,j}} \tag{A.10}$$

A.4. Additional descriptive information

See Fig. A.8 and Table A.8.

Table A.9
Table 2 for effect on trips.

	Trips (logs)
Treated product × Time	−0.04
	(0.17)
Treated product × Intervened route × Time	−0.08
	(0.18)

Each cell refers to a different regression. The first row refers to β in Eq. (7), the double difference specification. The second row refers to β_3 in Eq. (8), the triple difference specification. Unit of observation is route-year-product. The pre-period comprises one year before the enactment of price floors. The post-period comprises one year following the enactment of price floors. The number of observations in the double and triple difference specifications are 4214 and 14,700, respectively. Standard errors in parentheses, clustered at route level. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

A.5. Effect of price floors on the number of trips

See Fig. A.9 and Tables A.9 and A.10.

Appendix B. Supplementary data

Supplementary material related to this article can be found online at https://doi.org/10.1016/j.jpubeco.2024.105084.

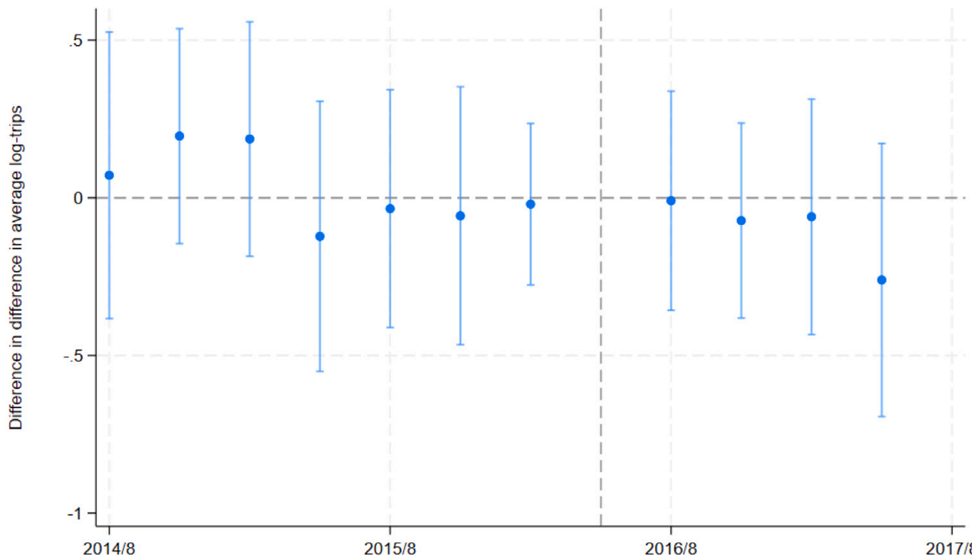


Fig. A.9. Fig. 5 for effect on trips.
The estimated equation is $ln(\text{Q}_{i,j,t}) = \sum_{t' \neq 0} \beta_{t'} [\mathbb{1}(t = t') \times \text{Treated product}_{i,j}] + \gamma_t + \gamma_{ij} + u_{i,j,t}$. Each point is the difference in difference coefficient for treatment vs. control in each quarter. The base quarter is 2016/5 - 2016/7, the last free market quarter. The unit of observation is route-quarter-product level. Confidence intervals at the 95% level with standard errors clustered at route level.

Table A.10
Table 3 for effect on trips.

	Trips (logs)
Two way fixed effects	−0.13
	(0.77)
DID_M	−0.32
	(1.31)

Each cell refers to a different regression. The first row refers to β in the continuous version of Eq. (7), the two-way fixed effect estimator, which is biased. The second row refers to the DID_M estimator proposed by de Chaisemartin and D'Haultfoeuille (2020), which is unbiased under the parallel trends assumption. In both cases the continuous treatment is defined as in Eq. (9). The unit of observation is route-year-product. The pre-period comprises one year before the enactment of price floors. The post-period comprises one year following the enactment of price floors. The number of observations in both specifications is 4214. The average of the continuous treatment variable at the route-product level is 0.13. Standard errors in parentheses, clustered at route level. For the DID_M estimator, standard errors are obtained through a bootstrap of 10,000 iterations. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

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