High profits and cost shocks in the fuel market: the role of demand adjustment costs

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Abstract

This paper shows that, with demand-adjustment frictions, firms can increase short-run profits in the presence of cost shocks. Firms exploit short-term price inelasticity by balancing current markups against future demand. We further examine the incidence of temporary profit taxes and find that, due to dynamic price-setting, the classic neutrality result no longer holds: firms temporarily lower prices to shift profits across tax periods, thereby increasing consumer welfare. We use this model to compare a profit tax, a price cap, and a fuel discount to the case of no policy intervention.

Keywords: Excess profit, demand adjustment friction, endogenous markup, profit tax, oil price shock

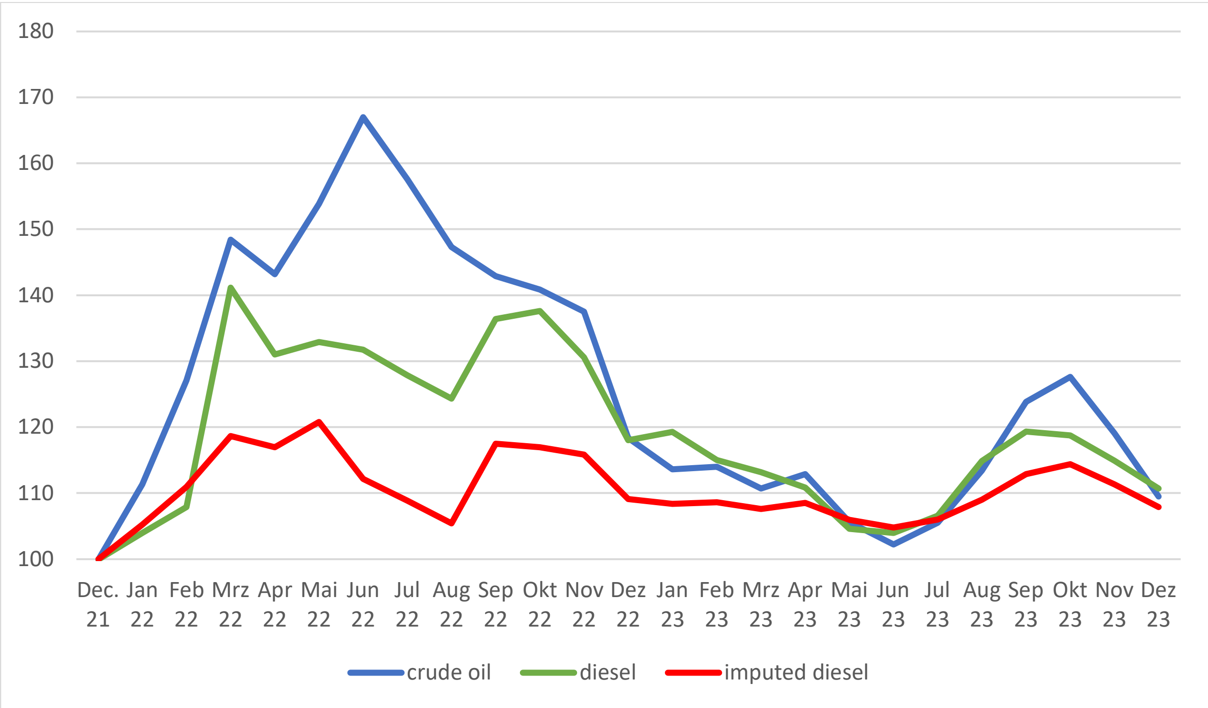
JEL: E3, E31, E32, H25

1. Introduction

Oil prices surged sharply in spring 2022 after Russia's attack on Ukraine and the resulting sanctions. Fuel prices worldwide rose disproportionately, causing a spike in inflation mainly blamed on companies exploiting market conditions, often called "greedflation." Rising profits in the oil and fuel sectors sparked public debate and prompted calls for taxing so-called excess profits. Meanwhile, competition authorities began examining pricing behavior in energy markets more closely, and governments implemented various measures to fight high fuel prices, such as price caps and fuel discounts.

Germany provides a particularly insightful example. From January to July 2022, crude oil prices rose by about two-thirds, while the average diesel sales price increased by roughly one-third (see figure 1). Since crude oil costs account for only about 30 percent of the diesel sales price and taxes usually make up more than half of the final price, a constant markup would suggest a much smaller price increase of around one-fifth. This shows that markups temporarily increased in response to the cost shock. Importantly, this deviation was not permanent: about a year after the shock, actual prices and prices implied by consistent markups converged again, indicating a return to the pre-shock pricing strategy.

Figure 1: Fuel prices, Dec2020=100



These price dynamics led to both regulatory and fiscal responses. The Federal Cartel Office (2022) highlighted the decoupling of crude oil input prices from refinery and gas station prices since the war in Ukraine started and launched an investigation into refineries and wholesalers.

Its final report emphasized the risk of collusion at the wholesale level and suggested corrective measures (Federal Cartel Office, 2025). To tax excess profits in the fuel sector, the German federal government introduced a "mandatory temporary solidarity contribution" in accordance with EU Council regulation 2022/1854 (EU Council 2022, Federal Ministry of Finance 2022). The measure imposed a 33% tax—on top of existing taxes—on profits in fiscal years 2022 and 2023 that exceeded 20% of a company's four-year average. This tax brought in about EUR 2.4 billion in revenue over the two years (Deutscher Bundestag, 2025).

A key challenge in interpreting these developments is that they are at odds with standard macro-pricing frameworks. These models suggest that firms mostly maintain their markups stable or absorb some of the higher input costs by temporarily reducing profit margins, reflecting factors such as demand sensitivity, competitive pressure, or nominal rigidities. The sharp price increases observed after the 2022 oil price shock show that firms' ability or willingness to absorb costs was temporarily limited. To understand markup dynamics and inflation following large supply shocks, it is essential to explain why firms increased their markups rather than partially absorbing the cost increase, and to identify the conditions under which cost absorption breaks down.

This paper contributes to this debate by proposing a parsimonious mechanism through which cost shocks cause endogenous, time-varying markups even in otherwise frictionless pricing environments. The key element of the model is sluggish demand: consumers face adjustment costs when changing their demand in response to price movements. These adjustment costs make short-term demand inelastic, creating incentives for firms to vary markups over time as marginal costs change. After a positive cost shock, firms optimally raise markups by exploiting the temporary inelasticity.

A second contribution concerns the incidence of excess profit taxation. Traditional analyses usually assume static demand and constant markups, implying that firms fully bear the tax burden. Our model demonstrates how intertemporal pricing causes expected temporary profit taxes to be non-neutral. Specifically, firms strategically lower prices during high-tax periods to shift profits to times with lower taxes, which partly benefits consumers and leads to a non-standard tax incidence.

We use this model to analyze the case for an excess profit tax. Considering the full dynamic adjustment of prices, quantities, and profits to cost shocks shows that rising profits are a short-term phenomenon, because declining current and future demand lowers profits in subsequent periods. As a result, firms end up with a lower present discounted value (PDV) of profits than they would have without cost shocks. This makes it more complicated to justify a profit tax economically. In this paper, we suggest three criteria for assessing policy effects: a distributional criterion that balances losses to consumers and firms in the fuel market; a fuel price stability criterion; and a budgetary criterion. We calibrate the model to match key features of the German fuel market, including cost structures and average profit margins.

The paper relates to three strands of the literature. First, it contributes to the rapidly growing research on inflation after the 2022 oil price shock, examining whether increased profits contributed to the recent inflation surge. Using national accounts data, European Central Bank (2023), European Commission (2023), and Hansen et al. (2023) find that unit profits significantly contributed to euro-area producer price inflation in 2022, with profit shares rising mainly in commodity-sensitive sectors. However, higher profit shares do not necessarily indicate higher markups and greater pricing power. Colonna et al. (2023) and Hahn (2023) show that profit shares and markups can diverge depending on production technology, and they document varied markup dynamics across countries and sectors. Glover et al. (2023a, 2023b) find that markups contributed to U.S. inflation in 2021 but had less impact in 2022. Firm-level data also shows mixed results. Koppenberg et al. (2025) and Blijens et al. (2023) mainly attribute recent price increases to rising input costs, while Bukold (2022) and the Federal Cartel Office (2025) report higher markups in energy markets.

Second, this paper relates to the theoretical literature on endogenous markups, beginning with the influential work of Rotemberg and Woodford (1992). Their research initiated a broad body of work that connects markup dynamics to market structure and competition, including models featuring endogenous entry and exit, or shifts in firm composition (e.g., Ghironi and Melitz, 2005; Carvalho and Gabaix, 2013). Models with endogenous markups applied to energy price increases in 2022 highlight demand-side and informational mechanisms through which markups rise after (supply) shocks, such as reduced demand elasticity during inflation (Scanlon, 2024), anticipatory pricing in response to expected cost hikes (Glover et al., 2023a, 2023b), precautionary pricing under cost uncertainty (Krebs and Weber, 2024), and shock-induced coordination among large firms (Weber and Wasner, 2023). A related strand examines supply-side channels, demonstrating how reservation profits, capacity limits, and endogenous exit constrain effective supply and contribute to profit-driven inflation in New Keynesian models (Kharroubi and Smets, 2024).

Third, the paper contributes to the literature on excess (or windfall) profit taxation. In their survey, Schwerhoff et al. (2020) examine the potential of economic rents as an efficient tax base. In traditional public-finance models, firms view excess profit taxes as lump-sum and do not change prices or quantities, meaning the tax is fully borne by firms and does not distort economic decisions (e.g., Auerbach, 1985; Devereux and Freeman, 1991). This neutrality depends, among other factors, on static demand and constant markups. More recent research relaxes these assumptions and shows that profit taxes are not always neutral under state-dependent pricing. Don Vito et al. (2023) provide event-study evidence of financial market reactions to temporary windfall taxes on banks, while Rao (2018) demonstrates that a U.S. windfall profit tax led to declines in oil production and investment. Recent policy evaluations by the International Monetary Fund (Hebous et al., 2022) and the European Parliament (2023) analyze the design, revenue potential, and distributional impacts of temporary excess profit taxes, emphasizing that their incidence heavily depends on firms' pricing strategies and market conditions, not just statutory design.

The rest of the paper is organized as follows. Section 2 introduces the model and explains the role of a profit tax. Section 3 presents the model calibration, which reflects cost structures and profit margins in the German diesel fuel market. Section 4 simulates the welfare effects of temporary cost shocks of different durations and a temporary tax on excess profits. In Section 5, we compare three common tools used to address high fuel prices: a price cap, a profit tax, and a fuel discount. Section 6 concludes.

2. The Model

We examine the fuel market. Fuel is supplied by a small number of large firms (i = 1, ..., I) because of high fixed costs, such as those for refineries and distribution networks. Firm i sells a product that is a (nearly) perfect substitute for fuel offered by other firms. All firms have identical technologies. We analyze the response of the representative firm to a common sector-wide cost shock, specifically an increase in the price of oil. Because the shock is common, firms can assume that all other firms make identical pricing decisions. ($P_t^{O,i} = P_t^{O,j} = P_t^O$). Alternatively, we can assume that all firms in the sector collude. Therefore, the relevant price elasticity for firm i is the price elasticity of total fuel consumption. This implies that firms jointly maximize profits in the fuel sector.

Demand for fuel

Households and firms in the transportation sector have identical CES preferences over fuel O_t and an aggregate of other goods and services Z_t which are substitutes to driving a car or truck with a combustion engine. The elasticity of substitution between these alternative modes of transportation is given by σ

$$X_t = \left[{s^Z}^{\frac{1}{\sigma}} Z_t^{\frac{\sigma-1}{\sigma}} + {s^O}^{\frac{1}{\sigma}} O_t^{\frac{\sigma-1}{\sigma}} \right]^{\frac{\sigma}{\sigma-1}}. \qquad (1)$$

They face quadratic adjustment costs for changing the level of fuel consumption

$$ADJ(O_t) = \left(\frac{P_t^O O_t}{P_t^X}\right)\frac{\gamma}{2}\left(\frac{\Delta O_t}{O_{t-1}}\right)^2$$

Customers in the fuel market face prices P_{t+j}^X, P_{t+j}^O and fuel prices can be subject to a fuel discount at rate s_t^O. The period budget constraint for energy (in real terms) is given by

$$X_t = \left(\frac{P_t^Z}{P_t^X}\right) Z_t + \left(\frac{P_t^O(1-s_t^O)}{P_t^X}\right) O_t \left(1 + \frac{\gamma}{2}\left(\frac{\Delta O_t}{O_{t-1}}\right)^2\right). \qquad (2)$$

The maximization problem of the representative consumer

$$\mathcal{L} = \sum_{t=0}^{\infty} \beta^j \log(X_t) - \beta^t \lambda_t \left(X_t - \left(\frac{P_t^Z}{P_t^X}\right) Z_t - \left(\frac{P_t^O(1-s_t^O)}{P_t^X}\right) O_t \left(1 + \frac{\gamma}{2}\left(\frac{\Delta O_t}{O_{t-1}}\right)^2\right)\right) \qquad (3)$$

yields demand functions for Z_t and O_t for $t \geq 0$

$$s^{Z\frac{1}{\sigma}}\left(\frac{X_t}{Z_t}\right)^{\frac{1}{\sigma}} = \left(\frac{P_t^Z}{P_t^X}\right) \tag{4a}$$

$$s^{O\frac{1}{\sigma}}\left(\frac{X_t}{O_t}\right)^{\frac{1}{\sigma}} = \left(\frac{P_t^O(1-s_t^O)}{P_t^X}\right)\left(1+\gamma\frac{(O_t-O_{t-1})}{O_{t-1}} - \beta\gamma\frac{(O_{t+1}-O_t)}{O_t}\right). \tag{4b}$$

As shown in Appendix 1, from the FOC w. r. t. O_t we can derive a dynamic demand equation, neglecting second-order terms

$$O_t = O_{t-1}^{\lambda_1}\exp\left(\frac{1}{\beta\sigma\gamma}\frac{1}{\lambda_2}(sp + xp_t - \sigma pp_t^O)\right) \tag{5}$$

with $\lambda_1 < 1$ and $\lambda_2 > 1$ and where

$$sp = \log(S^O) + \left(\frac{1}{\lambda_2}\right)sp \tag{6a}$$

$$xp_t = \log(X_t) + \left(\frac{1}{\lambda_2}\right)xp_{t+1} \tag{6b}$$

$$pp_t^O = \log(P_t^O(1-s_t^O)) + \left(\frac{1}{\lambda_2}\right)pp_{t+1}^O. \tag{6c}$$

The short-run price elasticity of demand is given by $\sigma^S = \frac{1}{\beta\sigma\gamma}\frac{1}{\lambda_2}\sigma$. As shown in Appendix 1, $\sigma^S$is smaller than the long run price elasticity σ.

Fuel producer

There are a small number of fuel producers. They sell a homogeneous good and face identical demand and cost functions. They implicitly collude and divide the market equally between the producers. This is implemented by jointly maximizing the present discounted value (PDV) of profits with discount factor β, where $O_t(P_t^O, P_{t+1,}^O \dots O_{t-1})$ denotes total demand for fuel (see eq. 5)[1]

$$Max\ V_0^{O^S} = \sum_{t=0}^{\infty}\beta^t(1-t_t^O)(P_t^O - mc_t)O_t\,(P_t^O, P_{t+1,}^O \dots O_{t-1}) \tag{7}$$

To simplify the analysis, we assume that marginal costs mc_t are exogenous and do not depend on the level of output, i.e., constant returns to scale w. r. t. variable factors of production. However, marginal cost can be subject to exogenous shocks ε_t^{mc}, e.g. resulting from shocks to oil prices. Thus

$$mc_t = mc + \varepsilon_t^{mc} \tag{8}$$

[1] The demand function also depends on current and future total spending, which we neglect here since we keep total spending constant throughout our analysis.

where $\varepsilon_t^{mc} = \rho^{mc}\varepsilon_{t-1}^{mc} + \vartheta_t$ can be autocorrelated. Firms can be subject to a profit tax with rate t_t^O. It is important to note that we regard physical capital as fixed, and firms in the fuel markets make pricing decisions by maximizing economic rents, i.e., the difference between prices and marginal cost. Therefore, the profit tax, as defined here, is a tax on economic rents (rather than on capital). In our analysis below, we assume that t_t^O will be zero, but the government can temporarily impose a tax on economic rents.

In each period t, the firm equates the PDV of marginal revenue to current and expected marginal cost

$$\frac{\partial V_0^{O^S}}{\partial P_t^O} = (1 - t_t^O)\left(O_t + P_t^O \frac{\partial O_t}{\partial P_t^O}\right) + \beta(1 - t_{t+1}^O)\left(P_{t+1}^O - mc_{t+1}\right)\frac{\partial O_{t+1}}{\partial O_t}\frac{\partial O_t}{\partial P_t^O} + \cdots = (1 - t_t^O)mc_t \frac{\partial O_t}{\partial P_t^O} \tag{9a}$$

This results (see Appendix 2 for a detailed derivation) in the following pricing rule, where prices are set as a markup over current marginal cost minus the PDV of profits from t=1 onwards, with discount factor $\beta\lambda_1$.

$$P_t^O = \frac{1}{\left(1 - \frac{1}{\sigma^S}\right)}\left(mc_t - \frac{1}{(1 - t_t^O)O_t}\sum_{j=t+1}^{\infty}(\beta\lambda_1)^j\left(1 - t_j^O\right)\left(P_j^O - mc_j\right)O_j\right) \tag{9b}$$

The markup over current marginal cost equals the inverse of the short-run price elasticity of demand σ^S. Since the short-run price elasticity of demand is low, this implies a large markup. However, as shown in equation (9) the short-run price elasticity of demand does not fully determine the price in period t. The second term on the RHS of equation (9) captures the negative effect on future profits of a high price in period t because of demand adjustment frictions. This equation reflects the intertemporal trade-off faced by the firm in case of demand adjustment frictions. The firm considers the low short-run price elasticity when setting prices. Prices are lower than implied by the short-run price elasticity because the firm anticipates that low current demand, driven by high prices today, will persist into the future. The discount factor on future profits depends on the rate of time preference β and the parameter λ_1, which is constrained between zero and one and which increases with the adjustment cost parameter γ. Given the values chosen for β, σ and γ, $\sigma^S < \sigma$ and the price-cost margin ($\frac{P_0^O}{mc_0}$) is larger under demand adjustment frictions. As shown in Appendix 2, the steady state markup is given by

$$\left(1 - \frac{1}{\sigma^G}\right)P^O = mc \tag{10}$$

With $\sigma^G = \sigma^S\left(\frac{1}{1-\beta\lambda_1}\right) > \sigma^S$, which implies that the steady state markup is smaller than implied by the short-run price elasticity. In Appendix 2 we also show that $\sigma^G < \sigma$. Thus, the steady state markup under sluggish quantity adjustment exceeds the markup charged by firms without sluggish demand adjustment. Without adjustment frictions $\sigma^G = \sigma^S = \sigma$ holds.

The effects of a profit tax

The price-setting rule shows how, in the presence of demand adjustment frictions, firms respond to temporary and permanent changes in the profit tax. As can be seen from equation (9), a constant permanent profit tax does not affect prices. Since in the absence of demand adjustment frictions ($\gamma = 0$), λ_1 is equal to zero and $\sigma^S = \sigma$, the dynamic price setting rule converges to the static rule with a non-distortionary profit tax. However, in case of $\gamma > 0$ a temporary profit tax increase ($t_0^O > t_t^O, t = 1,2, \ldots$) reduces prices. This price response can be interpreted as an attempt to shift profits to future periods and thereby avoid profit taxes. Again, it reflects the intertemporal trade-off faced by the firm in the presence of demand adjustment frictions. Lowering prices today reduces current profits but increases future profits because of higher demand in future periods.

3. Calibration

In our empirical analysis we assume that the variable cost function is the dual of the Leontief production function

$$O_t = Min(\frac{1}{s^{OIL}}\, OIL_t, \frac{1}{s^D}\, D_t, \frac{1}{t^e}\, TE_t) \tag{11}$$

where oil (OIL_t) is combined in fixed proportions $\frac{1}{s^i}$ with domestic variable factors of production such as labor, energy, transport services, etc. (D_t) and taking account of the energy tax (TE_t), where t_t^e is the energy tax rate per unit of output. Total variable costs are given by

$$C_t(O_t) = P_t^{OIL} OIL_t + P_t^D D_t + t_t^e O_t = P_t^{OIL} s^{OIL} O_t + P_t^D s^D O_t + t^e O_t \tag{12}$$

and costs per unit of output as a proxy for marginal costs by

$$\frac{C_t(O_t)}{O_t} = MC_t = s^{OIL} P_t^{OIL} + s^D P_t^D + t^e. \tag{13}$$

The gross profit margin GPM based on fuel price P_t^O, excluding VAT, is calculated as

$$GPM_t = \frac{P_t^O O_t - C(O_t)}{P_t^O O_t} = \frac{P_t^O - (s^{OIL} P_t^{OIL} + s^D P_t^D + t^E)}{P_t^O} \tag{14}$$

Based on the costs per unit of output $\frac{C_t(O_t)}{O_t}$ and shares of the cost components s^iwe calculate the imputed diesel price that oil companies would have charged if they had maintained their pricing strategy after the oil price shock of 2022. Figure 1 relates this imputed price to market fuel prices. While crude oil prices increased by about two-thirds from December 2021 to June 2022, the diesel sales price rose by roughly one-third over the same period. Note that diesel prices at the pump were reduced by approximately 8–9% between June 1 and August 31, 2022, due to a reduction in the energy tax by the German government. Had oil companies not altered their pricing strategies and kept their markups steady, the imputed diesel price would have only increased by one-fifth. Comparing the market price with the imputed diesel price indicates that the markup increased by roughly 15–20 percentage points in the first half of 2022. This deviation was temporary: around a year after the shock, market prices and prices implied by constant markups converged once again, indicating a return to pre-shock pricing strategies.

Table 1 summarizes the respective parameter values.

Table 1: Parameter values

Structural parameters		Values
Share of oil in variable production cost (incl. energy tax)	s^{OIL}	.31
Share of other costs in variable production cost (incl. energy tax)	s^{D}	.14
Share of energy tax in variable production cost (incl. energy tax)	t^{E}	.55
Discount factor	β	.99
Elasticity of substitution between Z and O corresponds to long-run price elasticity without adjustment costs	σ	20
Adjustment cost parameter	γ	.6
Short-run price elasticity of fuel	σ^{S}	1.25
Long run (inverse) price cost margin	σ^{G}	4.94

We select additional parameters, such as the elasticity of substitution, to ensure our model matches empirical profit rates in the German fuels industry. From an accounting standpoint, gross profit is the relevant measure, defined as revenue minus average variable costs, which serve as proxies for marginal costs. Specifically for the fuels industry, gross profit is calculated as revenue minus costs of production and distribution, including expenses for crude oil, transportation, refining, storage, energy, and CO2 taxes. As standard practice, these values are net of VAT. We apply a gross profit rate of 20%, consistent with sector data and the financial results of major companies like Shell and BP, the largest players in the German fuel market. Unsurprisingly, margins can vary considerably among firms, depending on their specific business models, such as oil refiners and wholesalers (Morningstar, 2020-2024).

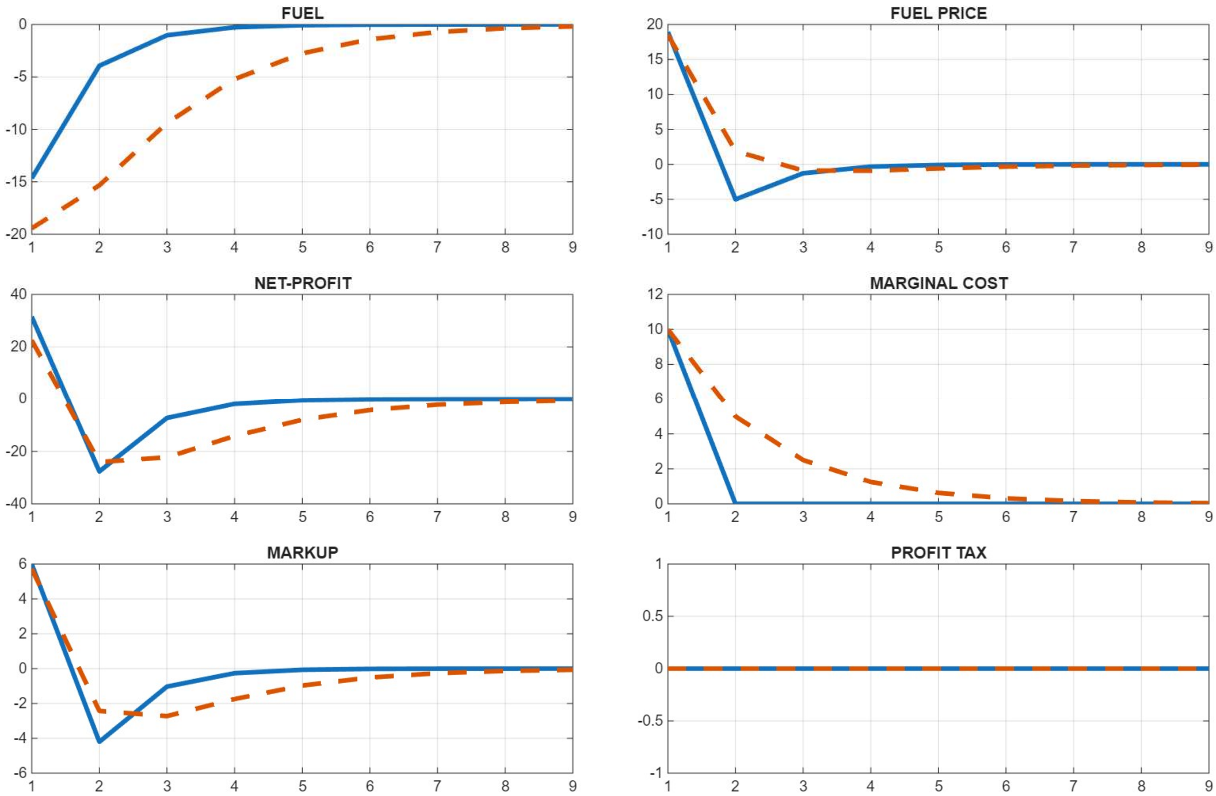
To achieve this profit rate, we select appropriate values for the elasticity of substitution, σ, and the adjustment cost parameter, γ. We choose values for σ and select the highest γ that keeps the solution determinate. Following this calibration approach, we set σ = 20 and γ = 0.6, which yields an elasticity of substitution for the generalized model of $\sigma^{G} = 5$, matching the empirical gross margin of 20%. An extensive sensitivity analysis indicates that the empirical results are qualitatively robust to alternative parameter values.

4. Model properties

4.1. Temporary cost shocks

We consider a scenario where firms face a 10% increase in costs in one period (Figure 2, solid line). In the first period, firms in the fuel market raise their markup by 6 percentage points (+6pp) and increase prices by more than marginal cost (+20%). They account for the low short-run price elasticity caused by consumers' adjustment costs. As a result, demand decreases by less than 20%. The low short-run price elasticity enables firms to boost profits during this period. However, there is a limit to how much they can initially raise prices because higher prices now reduce demand not only in the current period but also in future periods. This trade-off between present and future demand constrains the size of the price increase today.

Figure 2: One period vs. persistent increase of marginal costs



___ one period cost shock; --- persistent cost shock ($\rho^{mc} = 0.5$)

All variables are reported in percent deviations, except for the markup which is reported in percentage points.

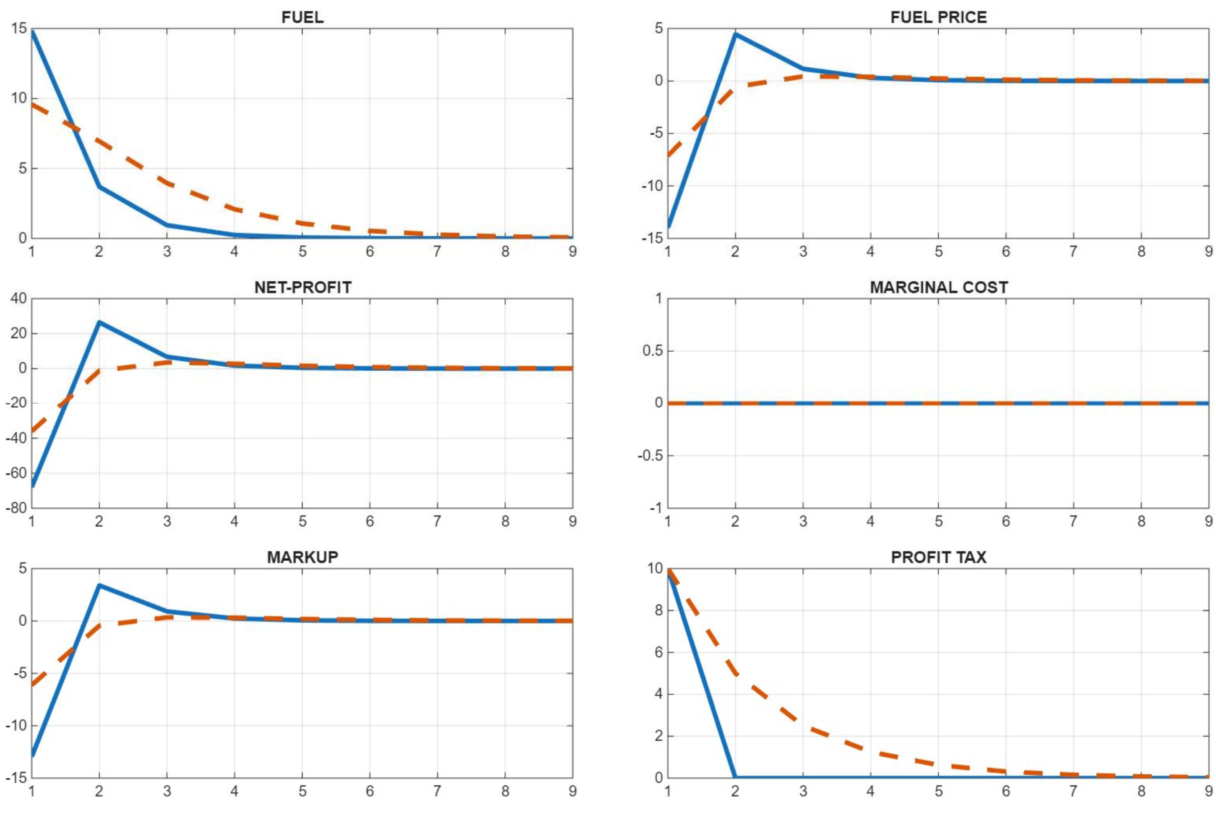
In the following period, firms lower their price markup below its long-term level (-3pp). Their strategy is to set a price that quickly restores demand to its long-term level, avoiding a prolonged period of low demand. They accept a lower profit in the second period in exchange for increased demand in future periods. More persistent shocks produce qualitatively similar results. (Figure 2, dashed lines for $\rho^{mc} = 0.5$). In particular, firms increase the price markup in the short run and lower it in subsequent periods. In this case, the markup declines less after period 1, and fuel prices do not temporarily undershoot the baseline.

The solution for profits involves an initial increase, followed by a temporary decline below the baseline in later periods. Additionally, firms cannot prevent the PDV of profits from decreasing. This outcome results from optimal price setting amid adverse cost shocks. The combination of higher short-term profits and a lower PDV of profits, however, complicates the case for an excess profit tax. We suggest a distributional criterion that is based on setting a profit tax balancing the PDV of profits with the welfare losses of downstream consumers. In a partial equilibrium setting of a fuel market (assuming no impact on consumer price levels or consumption of non-fuel goods), these welfare losses can be measured by the PDV of fuel consumption relative to the baseline.

4.2. Temporary profit taxes

As shown in section 2, a temporary profit tax is not neutral in a market with sluggish demand adjustment. It has the interesting property that firms find it optimal to temporarily lower prices to shift profits to future periods without a tax. This makes a temporary profit tax an interesting policy tool to not only redistribute "excess" profits but also to lower fuel prices. We consider a one-period profit tax and a temporary profit tax that declines at a 50% per-period rate.

Figure 3: Temporary profit tax (10%)



___ *one period profit tax;* --- *persistent profit tax* ($\rho^t = 0.5$)

Figure 3 shows that the firms' incentive to shift profits away from periods of high profit taxes is evident in the case of a one-period increase in the profit tax. Firms lower the price markup in period 1, which causes a reduction in fuel prices and lower profits during that period. This boosts demand in both the current and subsequent periods, leading to a markup and price increase in the following period when demand is high. Policy can achieve similar results by announcing a gradually decreasing profit tax, for example, in anticipation of a slowly declining marginal cost shock.

5. Comparing policy instruments in the fuel market

In this section, we evaluate various policy options, namely a price cap, an excess profit tax, and a fuel discount for consumers. We base our assessment of the three policies on how they perform, relative to a no policy benchmark, with regard to an equal distribution of losses for the demand and supply side of the fuel market, the stability of the fuel price, and budgetary costs.

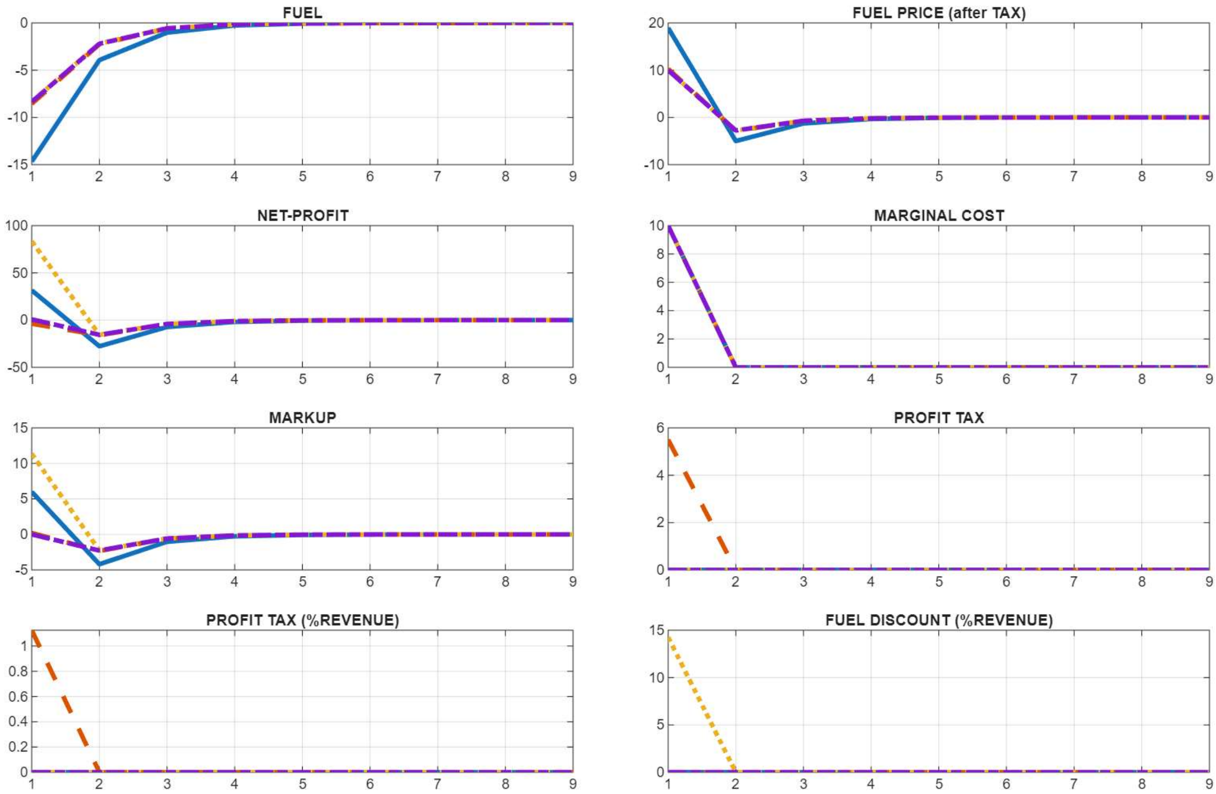
We examine a 10% marginal cost shock for one quarter. To ensure the policies quantitatively comparable, we choose the respective policy instrument so that the after-tax fuel price increases by the same amount. Starting with the price cap, we set it 10% above the pre-shock level, allowing for a fuel price increase without an unchanged markup. From the second period onward, firms return to their usual pricing behavior. Under a price cap, the fuel price is determined by the cap in the first period and by the optimal pricing rule for the firm from the second period onward.

$$P_t^O = \begin{cases} \frac{1}{\left(1-\frac{1}{\sigma^G}\right)} mc_t, \quad t = 0 \\ \frac{1}{\left(1-\frac{1}{\sigma^S}\right)}\left(mc_t - \frac{1}{(1-t_t^O)O_t}\sum_{j=t+1}^{\infty}(\beta\lambda_1)^j\left(1-t_j^O\right)\left(P_j^O - mc_j\right)O_j\right), t > 0 \end{cases} \tag{15}$$

We fix the profit tax at 5.5% such that firms find it optimal to increase prices by 10%. Finally, setting a one-period fuel discount of 14.25% also achieves an after-tax fuel price increase of 10%. Note that both the profit tax rate and the fuel discount cannot be adjusted ex ante; they require iteration because firms adjust the markup in response to these two policy measures.

Figure 4 provides information on the dynamic adjustment of the fuel market to the cost shock under alternative policy measures, while Table 2 shows how the measures perform across the three criteria.

Figure 4: Comparing fuel price measures



___ no policy; --- profit tax; ... fuel discount; --- price cap;

Table 2: Criteria for fuel price measures

	Distribution (1)	**Fuel price** (2)	**Budget** (3)
No intervention	0.04	20%	0
Price cap	-0.02	10%	0
Profit tax	-0.03	10%	1.1
Fuel discount	0.14	10%	-15

(1): $\Delta\left(\frac{PDV(Profit)}{PDV(Fuel)}\right) * 100$*, deviation from baseline; (2): Fuel price increase in period 1.; (3): Revenues (+)/Costs (-) (% of fuel revenue).*

No Intervention

This scenario was already discussed in section 4 and serves as a benchmark for the active policy scenarios. Based on our criteria, Table 2 indicates that without policy intervention, fuel suppliers lose relatively less than their customers and increase profits in the short term. The fuel price increase exceeds the cost increase by about 100%. Without policy intervention, the direct budgetary effects are zero.

Price cap

The price cap allows a full pass-through of the marginal cost increase into fuel prices at a constant markup in the first period. This restricts the price increase compared to the case of no policy intervention. From the second period onwards, firms lower their markups and prices below pre-shock levels. Compared with no policy intervention, the price cap distributes losses slightly in favor of the demand side of the fuel market. It also stabilizes fuel prices, and there are no budgetary costs, since firms are allowed to earn the same profit per unit of output as before the cost shock. Nevertheless, firm profits are reduced by declining fuel demand. Based on our criteria, the price cap is unambiguously an improvement over no policy intervention.

Profit tax

To make the first-period price effect of a profit tax comparable to the price cap, we introduce a 5.5% profit tax for one period, making it optimal for firms to increase fuel prices by only 10%, rather than 20% without a profit tax. This yields exactly the same price response compared to a price cap. Consequently, direct demand side losses are identical to the price cap. Because firms have to pay a profit tax for one period, losses are higher for firms. However, the profit tax generates additional revenues for the government budget. For the same degree of price stabilization, the profit tax does worse in terms of burden sharing but generates more budgetary space for the government.

Fuel discount

A fuel discount acts as a positive demand shock, inducing a positive markup response. To limit the first-period fuel price increase to 10%, a fuel discount of 14,25% is required. Thus, the fuel discount is shared between the two sides of the fuel market. After the first period, firms return to their pricing strategy. Because of our normalization, they encounter identical demand conditions in the second period under the two alternative policy options and consequently pursue identical price strategies after period two. Therefore, the fuel demand of households is identical to the other two measures. In terms of policy outcomes, the fuel discount differs from the other two measures in that it increases profits relative to consumer welfare beyond the no-policy-change scenario. In addition, this policy is costly for the government. Thus, based on these three criteria, the profit tax and the price cap are to be preferred.

6. Conclusion

This paper examines the influence of demand adjustment costs on dynamic pricing, markup fluctuations, and tax incidence. We develop a model where sluggish demand causes short-term inelasticity, enabling firms to increase markups over time in response to positive cost shocks. When consumers encounter adjustment frictions, optimal pricing deviates from constant-markup standards and becomes state dependent. Calibrating the model to key features of the German fuel market demonstrates how temporary cost shocks lead to time-varying markups and welfare losses caused by intertemporal demand distortions.

A key implication of the model concerns the incidence of temporary profit taxes. Unlike standard results derived under static demand, firms respond to temporary profit taxes by adjusting their prices over time, lowering prices during periods of high taxes to spread profits across different states. Therefore, demand adjustment costs alter traditional predictions about tax incidence and suggest that temporary profit taxes can partly benefit consumers through lower prices. Demand-side frictions also offer new insights into the effects of other policy measures such as a fuel discount and a price cap. We analyze alternative policies by examining their impacts on profits, consumer welfare, fuel price stability, and budget costs during the transition. We find that a profit tax and a price cap reduce and even overturn relative consumer welfare losses against suppliers in the fuel market. With sufficient information about demand and supply elasticities, the size of both measures could be tuned to balance losses for both sides of the market. A fuel discount also lessens welfare losses, but its effects are partly offset by higher firm markups and fuel prices.

More broadly, the analysis emphasizes demand-side frictions as a key factor influencing markup dynamics and policy transmission. Including demand adjustment costs in macro-pricing models offers a straightforward way to produce time-varying markups and unconventional policy effects. Future research could expand the framework to incorporate endogenous entry or general equilibrium settings to better understand how demand sluggishness impacts macroeconomic pricing behavior and policy design.

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Appendix 1: Deriving the dynamic demand function

Preferences for consumption of fuel O_t and alternatives Z_t are given by a CES function with elasticity of substitution σenergy consumption X_t

$$X_t = \left[s^{z\frac{1}{\sigma}} Z_t^{\frac{\sigma-1}{\sigma}} + s^{o\frac{1}{\sigma}} O_t^{\frac{\sigma-1}{\sigma}} \right]^{\frac{\sigma}{\sigma-1}} \quad \text{(A1)}$$

Quadratic quantity adjustment costs

$$Adj(O_t) = \left(\frac{P_t^O O_t}{P_t^X}\right) \frac{\gamma}{2} \left(\frac{\Delta O_t}{O_{t-1}}\right)^2 \quad \text{(A2)}$$

Lagrangian of the optimization problem

$$\mathcal{L} = \sum_{j=0}^{\infty} \beta^j \log\left(X_{t+j}\right) - \beta^j \lambda_{t+j} \left(X_{t+j} - \left(\frac{P_{t+j}^Z}{P_{t+j}^X}\right) Z_{t+j} - \left(\frac{P_{t+j}^O}{P_{t+j}^X}\right) O_{t+j} - \left(\frac{P_{t+j}^O O_{t+j}}{P_{t+j}^X}\right) \frac{\gamma}{2} \left(\frac{\Delta O_{t+j}}{O_{t+j-1}}\right)^2 \right) \quad \text{(A3)}$$

$$\frac{\partial \mathcal{L}}{\partial X_t} = \frac{1}{X_t} - \lambda_t = 0 \quad \text{(A4a)}$$

$$\frac{\partial \mathcal{L}}{\partial Z_t} = \frac{1}{X_t} s^{z\frac{1}{\sigma}} \left(\frac{X_t}{Z_t}\right)^{\frac{1}{\sigma}} - \lambda_t \left(\frac{P_{t+j}^Z}{P_{t+j}^X}\right) = 0 \Rightarrow s^{z\frac{1}{\sigma}} \left(\frac{X_t}{Z_t}\right)^{\frac{1}{\sigma}} = \left(\frac{P_{t+j}^Z}{P_{t+j}^X}\right) \quad \text{(A4b)}$$

$$\frac{\partial \mathcal{L}}{\partial O_t} = s^{O\frac{1}{\sigma}} \left(\frac{X_t}{O_t}\right)^{\frac{1}{\sigma}} - \left(\frac{P_t^O}{P_t^X}\right) - \left(\frac{P_t^O}{P_t^X}\right) \frac{\gamma}{2} \left(\frac{\Delta O_t}{O_{t-1}}\right)^2 - \left(\frac{P_t^O O_t}{P_t^X}\right) \gamma \left(\frac{\Delta O_t}{O_{t-1}}\right) \left(\frac{1}{O_{t-1}}\right) - \beta \left(\left(\frac{P_{t+1}^O O_{t+1}}{P_{t+1}^X}\right) \gamma \left(\frac{\Delta O_{t+1}}{O_t}\right) \left(\frac{-1}{O_t}\right) \right) = 0 \quad \text{(A4c)}$$

Ignoring quadratic terms yields

$$\frac{\partial \mathcal{L}}{\partial O_t} = s^{O\frac{1}{\sigma}} \left(\frac{X_t}{O_t}\right)^{\frac{1}{\sigma}} - \left(\frac{P_t^O}{P_t^X}\right) \left(1 + \gamma \left(\frac{\Delta O_t}{O_{t-1}}\right) - \beta\gamma \left(\frac{\Delta O_{t+1}}{O_t}\right) \right) = 0 \quad \text{(A4c')}$$

Henceforth we normalize prices relative to P_t^X which yields the demand function for O_t

$$S^{O\frac{1}{\sigma}} \left(\frac{X_t}{O_t}\right)^{\frac{1}{\sigma}} = P_t^O \left(1 + \gamma \frac{(O_t - O_{t-1})}{O_{t-1}} - \beta\gamma \frac{(O_{t+1} - O_t)}{O_t} \right)$$

(AA4c'')

and in logarithms

$$\frac{1}{\sigma} s^O + \frac{1}{\sigma}(x_t - o_t) = p_t^O + \gamma(o_t - o_{t-1}) - \beta\gamma(o_{t+1} - o_t) \quad \text{(A5)}$$

Solving for the dynamic demand equation

$$o_{t+1} - \frac{(1 + \sigma\gamma + \sigma\beta\gamma)}{\sigma\beta\gamma} o_t + \frac{1}{\beta} o_{t-1} = \frac{1}{\sigma\beta\gamma}\left(-s^O - x_t + \sigma p_t^O\right) \quad \text{(A6)}$$

Using lag operators, we can write eq. (6) as

$$(1\text{-}(\lambda_1 + \lambda_2)L + \lambda_1\lambda_2 L^2)o_{t+1} = \frac{1}{\sigma\beta\gamma}(-s^O - x_t + \sigma p_t^O) \tag{A7}$$

With $\lambda_1 < 1$ and $\lambda_2 > 1$. This yields the demand equation

$$o_t = \lambda_1 o_{t-1} + \frac{1}{\beta\sigma\gamma}\frac{1}{\lambda_2}\sum_{j=0}^{\infty}\left(\frac{1}{\lambda_2}\right)^j \left(s^O + x_{t+j} - \sigma p_{t+j}^O\right) \tag{A8a}$$

$$o_t = \lambda_1 o_{t-1} + \frac{1}{\beta\sigma\gamma}\frac{1}{\lambda_2}(sp + xp_t - \sigma pp_t^O) \tag{8b}$$

Where

$$sp = \log(S^O) + \left(\frac{1}{\lambda_2}\right)sp => sp = \frac{\lambda_2}{\lambda_2 - 1}s^O \tag{A9a}$$

$$xp_t = \log(X_t) + \left(\frac{1}{\lambda_2}\right)xp_{t+1} = x_t + \left(\frac{1}{\lambda_2}\right)xp_{t+1} \tag{A9b}$$

$$pp_t^O = \log(P_t^O) + \left(\frac{1}{\lambda_2}\right)pp_{t+1}^O = p_t^O + \left(\frac{1}{\lambda_2}\right)pp_{t+1}^O \tag{A9c}$$

NOTE: If adjustment cost $\gamma \to 0, => \lambda_1 \to 0, and\ \lambda_2 \to \infty, \frac{1}{\beta\sigma\gamma}\frac{1}{\lambda_2} \to 1$ this yields the static demand function

$$o_t = (s^O + x_t - \sigma p_t^O) \tag{A10}$$

The long run price elasticity in the dynamic case is also given by σ

$$\left(\frac{\sigma\beta\gamma}{\sigma\beta\gamma} - \frac{(1+\sigma\gamma+\sigma\beta\gamma)}{\sigma\beta\gamma} + \frac{\sigma\gamma}{\sigma\beta\gamma}\right)o = -\frac{1}{\sigma\beta\gamma}o = \frac{1}{\sigma\beta\gamma}(-s^O - x + \sigma p^O) \tag{A11a}$$

$$o_t = (s^O + x_t - \sigma p_t^O) \tag{A11b}$$

The log demand equation can be rewritten in levels

$$O_t = O_{t-1}^{\lambda_1}\exp\left(\frac{1}{\beta\sigma\gamma}\frac{1}{\lambda_2}(sp + xp_t - \sigma pp_t^O)\right) \tag{A12}$$

Appendix 2: Fuel producer

$$Max\ V_0^{O^S} = \sum_{t=0}^{\infty}\beta^t(1-t_t^O)(P_t^O - mc_t)O_t \tag{B1}$$

Taking the derivative of the PDV of profits w. r. t. the current price yields

$$\frac{\partial V_0^{O^S}}{\partial P_0^O} = (1-t_0^O)O_0 + (1-t_0^O)(P_0^O - mc_0)\frac{\partial O_0}{\partial P_0^O} + \beta(1-t_1^O)(P_1^O - mc_1)\frac{\partial O_1}{\partial O_0}\frac{\partial O_0}{\partial P_0^O} + \cdots = 0 \tag{B2}$$

Multiply with $\frac{P_0^O}{O_0}\left(\frac{O_0}{P_0^O}\right) = 1$

$$\frac{\partial V_0^{O^S}}{\partial P_0^O} = (1-t_0^O)O_0 + (1-t_0^O)(P_0^O - mc_0)\frac{\partial O_0}{\partial P_0^O}\frac{P_0^O}{O_0}\left(\frac{O_0}{P_0^O}\right) + \beta(1-t_1^O)(P_1^O - mc_1)\frac{\partial O_1}{\partial O_0}\frac{\partial O_0}{\partial P_0^O}\frac{P_0^O}{O_0}\left(\frac{O_0}{P_0^O}\right) + \cdots = 0 \tag{B3}$$

Rewrite in terms of the short-run price elasticity of demand $\left(\frac{\partial O_0}{\partial P_0^O}\frac{P_0^O}{O_0}\right)$

$$\frac{\partial V_0^{O^S}}{\partial P_0^O} = (1-t_0^O)O_0 + (1-t_0^O)(P_0^O - mc_0)\left(\frac{\partial O_0}{\partial P_0^O}\frac{P_0^O}{O_0}\right)\left(\frac{O_0}{P_0^O}\right) + \beta(1-t_1^O)(P_1^O - mc_1)\left(\frac{\partial O_0}{\partial P_0^O}\frac{P_0^O}{O_0}\right)\left(\frac{\partial O_1}{\partial O_0}\frac{O_0}{P_0^O}\right) + \cdots = 0 \tag{B4}$$

Where $\left(\frac{\partial O_0}{\partial P_0^O}\frac{P_0^O}{O_0}\right) = -\sigma^S$ and rearrange

$$\frac{\partial V_0^{O^S}}{\partial P_0^O} = (1-t_0^O)O_0 + (-\sigma^S)\left(\frac{1}{P_0^O}\right)\left((1-t_0^O)(P_0^O - mc_0)O_0 + \beta(1-t_1^O)(P_1^O - mc_1)\frac{\partial O_1}{\partial O_0}O_0 + \cdots\right) = 0 \tag{B5}$$

Or

$$(1-t_0^O)P_0^O O_0 = \sigma^S\left((1-t_0^O)(P_0^O - mc_0)O_0 + \beta(1-t_1^O)(P_1^O - mc_1)O_1\frac{\partial O_1}{\partial O_0}\left(\frac{O_0}{O_1}\right) + \cdots\right) \tag{B6}$$

Thus in contrast to a static markup pricing rule where the firm equates current revenue to current profit multiplied with the price elasticity of demand ($P_0^O O_0 = \sigma^S(P_0^O - mc_0)O_0$) it now equates current demand to the PDV current and future profits, where the discount factor β is adjusted for the speed of adjustment of demand to the change of demand in the current period $\frac{\partial O_k}{\partial O_0}\left(\frac{O_0}{O_k}\right)$

Since $\frac{\partial O_1}{\partial O_0}\left(\frac{O_0}{O_1}\right) = \lambda_1$ and $\frac{\partial O_k}{\partial O_0}\left(\frac{O_0}{O_k}\right) = \lambda_1^k$ we can write $\frac{\partial O_1}{\partial O_0}O_0 = \lambda_1 O_1$ and $\frac{\partial O_k}{\partial O_0}O_0 = \lambda_1^k O_k$

$$(1-t_0^O)P_0^O O_0 = \sigma^S((1-t_0^O)(P_0^O - mc_0)O_0 + \beta\lambda_1(1-t_1^O)(P_1^O - mc_1)O_1 + (\beta\lambda_1)^2(1-t_2^O)(P_2^O - mc_2)O_2 + \cdots) \tag{B7}$$

This can be formulated as a price setting rule (in analogy to the static price setting rule)

$$(1-\sigma^S)(1-t_0^O)P_0^O O_0 = -\sigma^S(1-t_0^O)mc_0 O_0 + \sigma^S(\beta\lambda_1(1-t_1^O)(P_1^O - mc_1)O_1 + (\beta\lambda_1)^2(1-t_2^O)(P_2^O - mc_2)O_2 +) \tag{B8}$$

Divide by $-(1-t_0^O)\sigma^S O_0$

$\left(1-\frac{1}{\sigma^S}\right)P_0^O = mc_0 - \frac{1}{(1-t_0^O)O_0}(\beta\lambda_1(1-t_1^O)(P_1^O - mc_1)O_1 + (\beta\lambda_1)^2(1-t_2^O)(P_2^O - mc_2)O_2 + \cdots)$ (B9)

<u>Steady state:</u>

Note $(1-t_t^O) = (1-t^O), for\ t = 0,1,2, \ldots$

$$P^O = \sigma^S\left((P^O - mc) + \beta\lambda_1(P^O - mc) + (\beta\lambda_1)^2(P^O - mc) + \cdots\right) \quad \text{(B10)}$$

This equation can be rearranged to yield the following steady state markup pricing rule

$$\left(1-\sigma^S\left(\frac{1}{1-\beta\lambda_1}\right)\right)P^O = -\sigma^S\left(\frac{1}{1-\beta\lambda_1}\right)mc \quad \text{(B11)}$$

Define the long-run (inverse) price-cost margin:

$$\sigma^G = \sigma^S\left(\frac{1}{1-\beta\lambda_1}\right) \quad \text{(B12)}$$

Then the steady state pricing rule with sluggish demand is given by

$$(1-t_0^O)P^O = \sigma^G(1-t^O)(P^O - mc) \quad \text{(B13)}$$

$$\left(1-\frac{1}{\sigma^G}\right)P^O = mc \quad \text{(B14)}$$

As shown in appendix :1 $\sigma^S = \frac{1}{\beta\sigma\gamma}\frac{1}{\lambda_2}\sigma$. Therefore

$$\sigma^G = \frac{1}{\beta\sigma\gamma}\frac{1}{\lambda_2}\left(\frac{1}{1-\beta\lambda_1}\right)\sigma \quad \text{(B15)}$$

It is easy to see that for $\gamma \to 0 => \lambda_1 \to 0, \lambda_2 \to \infty => \left(\frac{1}{\beta\gamma}\frac{1}{\lambda_2}\right)\frac{1}{1-\beta\lambda_1} \to 1, => \sigma^G = \sigma$. For values of σ and γ which are consistent with a gross profit margin of 25% we obtain $\sigma^G < \sigma$.