Energy Disruptions, Interfirm Price Effects and the Aggregate Economy

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Abstract

In an economy with many imperfect competitors (monopolistic competition), firms that pass through higher oil prices during a disruption will affect the demand for firms in other industries. Firms that charge higher prices for their final product will include the effect on their own final product in their private decisions but will exclude the effect on the final products of other firms. Although a pecuniary externality, these actions will reduce society's welfare, unlike the case of a perfectly competitive market. This situation creates a societal risk that is much wider than an externality in any single market. Policy interest shifts from one of punishing Persian Gulf oil producers to one of cushioning an industrialized economy from sudden disruptions caused by political and military conflicts. Although the value of reducing oil use depends upon a number of unknown parameters with wide distributions, a representative numerical example suggests that it may approach $5 per barrel.

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1. Introduction

Despite the very real and recent threats of Middle Eastern oil supply disruptions, energy economists disagree about whether public intervention is warranted. A change in a commodity's relative price is seldom a policy concern, even if that commodity is imported. It may be that the Organization of Petroleum Exporting Countries (OPEC) can artificially restrict its production to maintain monopolistic prices, but even on this point energy economists disagree. Bohi and Toman (1993, 1996) argue that OPEC generally lacks the market control to distort oil prices, although Greene, Jones and Leiby (1998)

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find that interpretation counter to a range of empirical studies suggesting that competitive oil prices should be about $7 per barrel.[1] However, OPEC's economic motives may be secondary. It seems that policymakers in importing countries may be more concerned about the speed and uncertainty of future oil price increases during disruptions rather than in whether current levels are too high relative to their marginal costs. In short, policymakers may be more concerned about what LaCasse and Plourde (1995) call a "random" shock due to military or political conflict than to a "strategic" shock manipulated by OPEC members for pure economic gain.

Folkerts-Landau (1984) and Bohi and Toman (1993, 1996) argue against policy intervention either before or during a "random" disruption because they do not find convincing evidence of a clear technical externality justifying such action.[2] Their discussion focuses on an economy (at least outside the oil market) characterized by perfect competition. They acknowledge that an oil import premium might apply to a large importing country under certain conditions but express little enthusiasm. Collective action by a large importing country can reduce the import price and improve the welfare

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[1] These estimates include some modest adjustments to account for the user cost for depletable resources. Replacing imported energy with domestic sources is sometimes argued to be a policy of draining America first. This explanation only makes sense if these user costs are large. Krauthammer (1986) explains why they may not be as large as was feared during the 1970s when artificial shortages emerged.

[2] Some earlier papers suggested that adjustment costs may also create externalities that would justify subsidies to domestic production or tariffs. Bhagwati and Srinivasin (1976) and Mayer (1977) argue that when an unanticipated disruption occurs, adjustment costs prevent producing firms from providing the lost good except at a very high price. Appropriate policy would be a subsidy to encourage more domestic production prior to a disruption because producers are undervaluing the commodity during normal times. Tolley and Willman (1977) expand this concept to include energy consumers with rigid capital stocks and long-standing habits. Since both consumers and producers of the embargoed commodity are undervaluing it, an oil tariff rather than a production subsidy is preferred. If firms and consumers correctly internalize the effects of future disruptions, however, their current private decisions will value the embargoed commodity properly. (Srinivasan, 1987).

of its citizens that could not be realized if each citizen acted independently of each other.[3] While such actions would not help during a disruption, the premium could reduce the costs of preparing the country for a disruption prior to its occurrence.

What appears to be lacking in the policy analysis discussion is the recognition that there may be public or societal risks that are not easily ameliorated by the financial and other institutions that private agents can use effectively. While these private institutions are appropriate for protecting the individual risks of a particular firm or consumer, they may be less well suited for addressing some of the complicated interactions that exist in any modern economy. The particular issue addressed in this paper is the interfirm effect between their pricing strategies. The macroeconomic literature has introduced a set of models that represent firms with some market power and whose pricing strategies affect other participants as well as their own firm.[4] Clearly, these conditions are quite different from the perfectly competitive markets evaluated in previous analyses and hence require some consideration by energy economists.

In order to keep the presentation relatively simple, the paper removes many complicating factors in framing the problem. The next section discusses oil disruptions and explains why they may be different from other events that cause relative prices to change. Section 3 provides some initial insights into the concept of interfirm price effects with a brief diagrammatic exposition. Section 4 develops a model of monopolistic competition, in which pricing strategies are interdependent. Section 5 provides some

[3] Plummer (1981) and Energy Modeling Forum (1981) provide clear explanations for the oil import premium. The existence and size of the gain depend upon whether there is retaliation by trading partners (Bowen, Hollander and Viaene, 1998, pp.164-170), the extent of cooperation by other importers (Bergstrom, 1982), and whether importers precommit when taking action with a depletable resource (Lapan, 1988, and Maskin and Newbery, 1990).

[4] Although they focus on microeconomic concepts, Cornes and Sandler (1996) briefly mention the macroeconomic literature on externalities.

estimates based upon the framework to show how large the effect might be. Although these estimates are only illustrative, they appear consistent with those estimated from larger macroeconomic simulation models. Conclusions are offered in the final section.

2. Disruptions and energy price changes

Although there exists econometric evidence that oil disruptions cause economic dislocations,[5] one might argue why should the price of energy rather than some other commodity be emphasized. The most direct response is that few other commodities have experienced such dramatic price jumps, represent about 5 percent or more of the economy depending upon energy price levels, are closely tied to specific and fixed capital stock, and are used so extensively through the economy in virtually all sectors.

In 1999, oil imports' economic value in the U.S. economy accounted for five times steel imports' economic value, and its value in 2000 is nearly twice that level. Over the March 1982-January 2002 period, the standard deviation in monthly oil prices was 29.5% of its mean, while the standard deviation in monthly steel prices was 9.2%.[6] Steel is often sold under long-term contracts that restrict price movements while many energy forms are not. In a comparison with other important commodity prices, Plourde and Watkins (1998) found that oil prices fluctuated more than or at least as much as the most volatile of these prices.

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[5] Mork (1994) and Hamilton (2001) review many of the available studies. I will accept their conclusions that disruptions properly defined do matter in the remainder of this paper.

[6] The data discussed in this paragraph are the U.S. imported prices for crude oil, for iron and steel products, and for coffee, cocoa and sugar, as reported by the U.S. Bureau of Labor Statistics (2002). U.S. Energy Information Administration (2001) reports the value of crude oil imports while the Steel Manufacturers Association (www.steelnet.org) citing a Credit Suisse/First Boston report is the source for the value of steel imports.

A commodity like coffee has experienced more price volatility than steel and its price experience is closer to oil; the standard deviation for the combination of coffee, cocoa and sugar prices was 27.8% over the same period. However, these products are not used nearly as widely as energy in all sectors. Coffee also has easy substitutes (tea, cold drinks with caffeine) and is not tied to a specific capital stock in the same way that energy is. Prices that influence the cost structure of all sectors, like energy, are the usual ones considered as potential supply shocks, such as wages, payroll taxes, sales taxes and general food price increases. This result underscores the point that an energy disruption is a supply shock much like these other possibilities.

The analysis will consider energy supply disruptions that dramatically raise the energy price path. Hamilton (2001) distinguishes between an external energy shock defined as a disruption and the normal oil price volatility that has characterized oil prices over much of the last 15 years. Firms have a much more difficult time anticipating and forecasting future price and demand conditions when they do not know the future oil price path. They are also less likely to have invested in contracts and other vehicles for reducing their price risk to these unanticipated events.

Another reason for focusing upon disruptions is that the empirical evidence finds that positive oil price shocks reduce economic activity but that negative oil price shocks have modest if any impact (Mork 1989, Hooker 1996, and Hamilton 1996 and 2001). The asymmetry finding is consistent with several different explanations for how oil prices affect the economy. If both positive and negative energy price shocks create short-run unemployment as resources shift from one sector to another, these shifts between sectors could dampen and even eliminate the otherwise positive effect resulting from a sudden energy price decline. Alternatively, if the real-balance effect for money is important, asymmetries in the wage and price response may translate into asymmetries in the change in the real money supply (the nominal money supply adjusted for the price level).[7]

3. Diagrammatic presentation of interfirm price effects

A diagrammatic explanation provides a useful initial perspective on the problem. Assume that there are multiple firms that each provides a differentiated final product[8] that is an imperfect substitute for other products. Products could be differentiated by location, quality, or certain other attributes valued by consumers. The degree of differentiation or competition among goods need not be a function of the number of firms, as would be the case if all firms sold the same standardized product.

The top half of Figure 1 shows the market conditions faced by each firm if the other firms' pricing strategies are ignored. Under these monopolistic competition conditions, each firm faces a demand curve that slopes downward as its own price falls relative to other prices in the economy.

For simplicity, each firm can produce each unit at a constant cost. Prior to the energy shock, it produces at Q_1 where its marginal revenue curve (MR_1) intersects the firm's marginal cost curve (C_1). It charges a price from its demand curve (D_1) that is consistent with this output level for profit maximization. This price, P_1, exceeds the marginal revenue or marginal cost at that output level.

[7] In the real-balance effect, higher energy prices will increase the aggregate price level and reduce the real money supply because wages and other prices are downward sticky. The reverse does not happen, however, when energy prices fall. Wages and prices are not restricted from rising to offset the effects of lower energy prices.

[8] The term "product" in this paper will always refer to the final goods or services produced by each firm rather than to an energy product produced by refineries or some other transformation within the energy sector.

Since consumers are paying too much for too little output relative to competitive conditions, the society loses welfare indicated by the shaded triangular area. At the margin, society's lost welfare equals the price markup, or the difference between price and marginal costs at Q_1 . At this output level, consumers pay a higher price, by an amount equal to P_1-C_1, for less output, Q_1, than under competitive conditions. This result is the standard deadweight loss associated with imperfect competition.

When energy costs increase, the firm's costs increase as depicted by the curve C_2. The firm will maximize its profits if it reduces its output to Q_2 and charges a higher price, P_2. This response describes the individual-firm effect. The diagonally marked quadrangular area in Figure 1 reveals the additional welfare loss from the shock. Imperfect competition magnifies the welfare loss because it now includes a rectangular as well as triangular area.

Now consider the aggregate economy's response if each firm follows the above pricing strategy. Seeking to maximize profits, each firm will have incentives to charge higher prices, because marginal costs exceed marginal revenues at the previous output level. However, if all firms raise their prices by the same amount, there will be no change in relative prices for the final output.[9] Consumers would have no incentives to shift their consumption from one product to another. However, firms cannot raise their prices and keep their output unchanged in the aggregate, unless the authorities provide additional money supply to accommodate the cost push.[10]

[9] The assumption of symmetric firms is made for tractability and consistency with the next section. Asymmetric firms would make the model more realistic but would not invalidate the interfirm price effects discussed here. They would also complicate the analysis considerably.
[10] Expanding the money supply would raise prices but not increase output in this model. Please see Appendix A.

This second effect emphasizing the aggregate demand influence is shown in the bottom half of this figure, where the initial cost curve (C_1) and the original marginal revenue curve (MR_1) are not shown for simplicity. However, the original demand curve $D(M/P_1)$ and P_2 are identical to their counterparts in the top half. As all firms seek to charge higher prices, the aggregate demand curve shifts inward from $D(M/P_1)$ to $D(M/P_2)$. Each firm will need to reduce its output more to Q'_2 if it wants to continue to maximize profits.

Thus, each firm operating independently of each other will produce a firm-level impact represented by the difference between Q_2 and Q_1. Its higher price will reduce aggregate demand, but by only a very small amount. However, the combination of all such independent actions will have a larger impact, as indicated by the difference between Q'_2 and Q_2.

This second effect is a pecuniary externality because firms are affecting other firms through the price system. The next section will demonstrate that this pecuniary externality will produce welfare losses when there is imperfect competition. These welfare losses from pecuniary effects do not exist when there is perfect competition. Thus, monopolistic competition not only introduces the standard dead-weight loss attributable to market power but it also raises the possibility that firms will experience economic effects from other firms' actions. In the real world, these interfirm price effects may be extremely difficult to anticipate as a disruption starts spreading through the economy. The planning environment for each firm appears to be substantially more complicated than when that firm operates under perfect competition or can adjust his production operations in response to a relative price change.

4. The model

The model is based upon the framework developed by Romer (1996: pp. 257-60) to explain price setting with imperfect competition. This approach builds upon a microeconomic foundation for aggregate relationships that allows estimation of welfare effects and that is quite useful for evaluating issues like cost shocks and monetary policy. It incorporates only the most rudimentary elements of aggregate macroeconomic conditions. It should also be emphasized that the model is a very small general equilibrium framework where factor owners provide all inputs and spend all income on the final product. To demonstrate that energy payments are not "lost" in this system, the model is simulated for various scenarios and output and real payments for profits, wages, and total energy payments are reported in the appendix.

4.1. The firm

There are multiple firms in a monopolistically competitive economy. Each firm is the principal supplier in a separate sector, sees a downward sloping demand curve for its product, and hence possesses some degree of market power. Firms may compete somewhat on commodity prices but their fiercest competition may be on other attributes, such as location, information, or quality. Thus, the imperfection does not arise from having too few firms in the economy but from having these barriers and attributes that separate the different sectors.

Each firm faces a downward-sloping demand curve and hence possesses some market power to push prices above marginal cost. This assumption is important and appears broadly consistent with empirical studies of individual industries (Breshnahan, 1989).

The firm's demand curve also depends upon the level of aggregate demand. A common approach that is adopted here is to represent aggregate demand as the nominal money supply (M) divided by the aggregate price level (P) for all goods. This specification represents the important condition that total real spending is an inverse function of the aggregate price level in a simple way. This approach can be considered either as a shortcut approach for representing aggregate demand or from a more refined model where real money balances and consumption both enter the utility function discussed below (Blanchard and Kiyotaki, 1987).

The demand curve for each good is

$$(1) \qquad q_i = Y\,(P_i / P)^{-\eta_i} = (M / P)\,p_i^{-\eta_i}$$

where q_i is the firm's output and $\eta_i > 1$ for stability for a profit-maximizing firm. Capital *P* represents nominal prices and small *p* denotes real prices. If *P* is a simple geometric average of all *k* goods prices and P_0 is its base year value, then p_i could technically influence its aggregate counterpart because

$$(2) \qquad P / P_0 = (P_i / P_0)^{\alpha_i} \prod_{j=1}^{k-1} (P_j / P_0)^{\alpha_j} = p_i^{\alpha_i} \prod_{j=1}^{k-1} p_j^{\alpha_j} \qquad \text{where } \sum_{i=1}^{k} \alpha_i = 1.$$

With numerous firms, however, the firm can change its own sector's price without appreciably influencing the aggregate price in the economy.

The aggregate price level (Eq. 2) has been expressed in a slightly more complicated manner than necessary in order to emphasize that both the individual firm and other firms can influence the overall price level. This relationship is based upon the money supply equation discussed previously and is essential not only to properly close the economy but also for the argument in this paper. Ignoring the money supply relationship is tantamount to assuming that firms operate as monopolistically competitive entities without any interdependencies.

Each firm uses a fixed amount of a common labor input, n_i, and a fixed amount of a common energy input, e_i, to produce a unit of its own final output.

(3) $$n_i = \phi_i q_i \quad \text{and} \quad e_i = \lambda_i q_i$$

where ϕ_i and λ_i can vary by firm. Fixed production coefficients are unsatisfactory for a longer-run analysis, but seem suitable and widely used in studies of oil disruptions (McGuire 1990 and 2000) and short-run price setting on the basis of costs (Dixon and Rankin 1994; Romer 1996).

Both inputs are provided in competitive markets. Laborers always remain on their aggregate labor supply curves. Domestic energy production is fixed exogenously at E_i*, with the remainder being provided from abroad. During disruptions, energy prices reflect the physical scarcity induced by temporary political events and wars that temporarily interrupt the market and reduces foreign supply. Once the disruption has passed, however, energy markets return to operating efficiently and the economies benefit from lower energy prices again. Each firm pays a real wage rate $w=W/P$ for each unit of labor and a real energy price of $h=H/P$ for each unit of energy.

It is simplest to consider the firm as being a "farmer" who is both a producer and an owner of labor and domestic energy. Each firm earns total profits equal to

(4) $$\pi_i = (p_i - w\phi_i - h\lambda)q_i = (p_i - w\phi_i - h\lambda_i)(M/P)p_i^{-\eta_i}$$
$$= P_0 M(\sum_{j=1}^{k-1} p_j^{-\alpha_j})(p_i^{1-n_i-\alpha_i} - p_i^{-\eta_i-\alpha_i}(w\phi_i + h\lambda_i))$$

In addition, he earns labor and energy income. The sum of profits and these two factor payments provides his income for consumption.

4.2. Pricing strategies and labor supply

This producer-worker agent's welfare depends upon his consumption (which equals his real factor income from wages and the return on domestic energy production plus profits) and foregone leisure according to the following simple utility function:

$$(5) \qquad U_i = C_i - (L^\gamma / \gamma) = (p_i - w\phi_i - h\lambda_i) q_i + wL_i + hE_i^* - (L_i^\gamma / \gamma) - (E_i^{*\varepsilon} / \varepsilon) \qquad \gamma > 1.$$

The last term represents the costs of domestic energy production.

The individual can change either price or labor input to maximize his utility. The firm will maximize profits by changing price until it lies above marginal costs according to the following first-order condition based upon Eq. 5:

$$(6) \qquad \begin{aligned} p_i &= [(\eta_i + \alpha_i)/(\eta_i + \alpha_i - 1)] \quad [\phi_i w + \lambda_i h] \\ &= [\eta_i/(\eta_i - 1)] \quad [w + h] \qquad \text{when } \phi_i = \lambda_i = 1 \quad \text{and} \quad \alpha_i = 0 \end{aligned}$$

This equation captures the importance of the interfirm price effects. The second equality reveals that the markup is the standard one for a monopolist based solely upon the price elasticity of demand, if each input unit produces one unit of goods and the firm observes no effect of his pricing strategy on the aggregate price level. Since there are multiple firms, α_i will approach zero for each small firm. However, this private strategy differs from one where firms internalize their interfirm price effects by setting $\alpha_i > 0$. Under these alternative conditions, the group would set lower product prices, and each firm's demand would grow with rising aggregate output.

It is important to recognize that price setting by the other firms will also influence firm i' s profits. In the two-firm case, an increase in firm j's price reduces firm i's profits by

$$(7) \qquad d\pi_i / dp_j = -\alpha_j (M / P_0) p_j^{-\alpha_j - 1} (p_i^{1-n_i-\alpha_i} - p_i^{-\eta_i-\alpha_i} (w\phi_i + h\lambda_i)) = -\alpha_j \pi_i / p_j$$

This adjustment operates through the economy's aggregate demand for all goods and services rather than through the demand for one good relative to another. When there are many firms, all firms are affected a little bit by firm j's price action. The total effect across all firms may be quite large relative to the effect internalized by the acting firm.

The individual will also change his labor supply (the second decision variable) until the real wage equals his lost leisure from working one more hour, according to the following first-order condition based upon Eq. 5:

$$(8) \qquad w_i = n_i^{\gamma - 1}$$

This relationship can be converted to a labor supply function, where 1/(γ-1) is labor supply's elasticity with respect to real wages.

4.3. The economy's output

Equilibrium wages, prices, output, and employment in the economy represent the aggregation of these individual production and labor supply decisions. It is customary in these models to consider multiple symmetric firms that each produce the same amount of output and supply the same amount of labor and domestic energy. These symmetric firms also use the same production process, which allows the subscript for ϕ and λ to be dropped. Under these conditions, we can replace the individual's labor supply with production from Eq. 3 and sum over all individuals. The real wage is determined by the equilibrium between the labor demand (Eq. 3) and labor supply (Eq. 8) curves and is a function of aggregate output:

(9) $$w = (\phi\, Y)^{\gamma - 1}$$

Since firms base their prices partly on real wages (Eq. 6), their desired relative price (with respect to the aggregate price level) will also be a function of output:

(10) $$p_i = [(\eta + \alpha)/(\eta + \alpha - 1)][\phi^{\gamma} Y^{\gamma - 1} + \lambda h]$$

When in equilibrium, each symmetric firm charges the same price. Thus, firm i's price equals the aggregate price level, $P_i = P$, or $p_i = 1$. Equilibrium output for these monopolistic competition conditions becomes:

(11) $$Y = \left\{[(\eta + \alpha - 1)/(\eta + \alpha)] - \lambda h\right\}^{1/(\gamma - 1)} \phi^{-\gamma/(\gamma - 1)}$$

Output is an inverse function of the price markup. Greater market power induces each firm to charge higher prices, which at the aggregate level causes less total spending in all sectors. If firms internalize their interfirm price effects completely, $\alpha = 1$. Under these conditions, they will set lower prices and sell more output.

Perfect competition is a special case worthy of some attention. Under these conditions, η approaches ∞ and the inverse of the markup approaches unity. The output level approaches

(11a) $$Y = \left\{1 - h\right\}^{1/(\gamma - 1)}$$

if $\lambda=\phi=1$. With perfect competition, the effect of other firms' prices on the aggregate price level (α) no longer influences the output level. This result underscores the importance of the assumptions about imperfect competition in the nonenergy sector of the economy. In addition, comparison of Eq. 11 with Eq. 11a shows that the monopolistically competitive economy underproduces relative to a perfectly competitive one.

5. Some simulation results

The preceding analysis provides results for output (Eq. 11), real wages (Eq. 9), and labor inputs (Eq. 8). These estimates can be substituted into the utility function (Eq. 5) to derive social welfare. They can be used to illustrate the basic concepts. After empirically investigating the response of industries to oil price changes, Rotemberg and Woodford (1994) suggest that a reasonable judgement is that firms set prices about 20% above marginal costs on average for the U.S. economy. With multiple firms and $\alpha=0$, that would imply $\eta=-6$. We further simplify by setting $\phi=\lambda=1$ and $h=0.05$. Thus, energy costs are about 5% of output costs.

With firms marking up costs by 20% and energy prices at their pre-shock level, aggregate output is calibrated to equal 8585 (which could be billion US dollars) by multiplying each firm's level by 10,000 firms. Real wages per labor unit equal .783. The sum of the net gain to labor (real wages minus lost leisure), the net gain to domestic energy producers (where the relatively small costs were assumed to be negligible), and profits is total welfare and equals 5819.[11]

[11] Appendix B reports these baseline results as well as those for the alternative cases discussed in this section.

Table 1. Simulated Percentage Impacts of a 50% Energy Shock

	Competition[a]	Shock	Shock w/ Internalization	Low Energy Shock
output	12.81%	-2.01%	-0.10%	-1.79%
aggregate price	-11.36%	2.05%	0.10%	1.42%
real wage	21.28%	-3.19%	-0.15%	-2.85%
labor inputs	12.81%	-2.01%	-0.10%	-1.79%
welfare	1.67%	-4.33%	-3.87%	-3.88%
monopolistic profits	-100.00%	-2.01%	-14.37%	-1.79%

[a] Competition case shows percentage change from monopolistic competition case without a shock.

The first column of Table 1 shows that this economy would appear dramatically different under perfect competition. Under competitive conditions, η approaches infinity and the markup ratio between prices and costs falls to unity. With the lower price level, the economy's real money supply and aggregate spending are larger. Aggregate output expands by 12.8%, and real wages increase by 21.3%, relative to the monopolistic competition solution. Monopolistic profits are eliminated, both labor income and lost leisure increase, and total welfare is 1.7% higher with competition than with monopolistic competition.

The second column of Table 1 shows the economy's response to an energy price shock of 50% under monopolistic competition conditions. The energy shock increases the prices of all firms by 2.0%. Aggregate output falls by 2.0%[12] and welfare by 4.3%. Monopolistic profits decrease because firms lose the margin (price minus marginal costs) on their lost output. Real wages and labor income fall. The initial conditions of

[12] The 2% decline in output from a 50% price shock appears between the first-year and second-year median impacts (1.4% and 3.0%, respectively) estimated in the Energy Modeling Forum's comparison of macroeconomic models in the early 1980s (as reported in Hickman *et al*, 1987). Hamilton's (2001) recent estimates places the impact after the first year (four quarters) also at 1.4% if the equation is estimated either prior to 1981 or through 1999 if one uses an instrumental variable to control for exogenous shocks.

monopolistic competition mean that the economy begins losing relatively large amounts of welfare as the energy shock reduces output.

Policymakers cannot overcome this problem simply by increasing the number of firms, because each additional firm will be producing a different product rather than competing on price for a single product. The substitution elasticity between products in each firm's demand schedule reflects location, quality and other product attributes and need not change if there should be more firms. However, changes in the way that firms price their product can move the economy closer to its socially optimal level. Under the pricing rules in the previous energy price shock case, each firm ignored the effect of its pricing strategy on other firms. Its effect on the aggregate price level was very small compared to its effect on the firm's own profit-maximization position. However, suppose that in response to the sudden energy price shock, the economy adopted rules or guidelines that had firms incorporate these external effects. An example might be cost and price guidelines to dampen the effect on prices. Each firm would be aware that its pricing strategy reduced all firms' output through its effect on the economy's aggregate price level. If totally effective, these new conditions would change $\alpha=0$ to $\alpha=1$ in the price mark-up relationship (Eq. 6). Firms would charge prices that were 16.7% rather than 20% above marginal costs because their lower prices would expand aggregate real spending.[13]

[13] This cooperation case is based upon a single unique equilibrium in which firms alter their pricing strategies to maintain higher aggregate demand. It is separate from the coordination failure hypothesis, in which there may be multiple equilibria, as advanced by Cooper and John (1988).

Column 3 of Table 1 summarizes the results. Under these conditions, prices would rise by only 0.1% rather than by 2.0% (comparing the third with the second column). The economy's output would fall by only 0.1% rather than by 2.0% and its welfare would decline by 3.9% rather than by 4.3%. By restricting firm prices from reaching profit-maximization levels after the shock, this policy causes monopolistic profits to plummet.[14]

Anti-trust legislation would most likely not allow cooperative pricing. Moreover, government programs like wage-price guidelines are unlikely to be achieved efficiently when asymmetric firms have widely different price elasticities of demand and input intensities. General economy-wide rules governing the pass through of costs in each industry could lead to significant distortions.

Despite its limitation as a viable policy option, this cooperation case underscores that conceptually there may be opportunities to reduce the negative effects of a disruption. The economy would need to expand output without affecting firm prices. Changing the firm's pricing strategy to incorporate its effect on other firms can improve welfare. Despite operating through prices and being pecuniary, this externality influences welfare. Ordinarily, economists ignore such externalities because they do not influence welfare under perfect competition. With imperfect competition, governments may be concerned about pecuniary externalities induced by pricing strategies because they can harm welfare.

[14] This cooperation case assumes that firms agree to a program for passing through the costs without making the industries any less competitive, i.e., η remains the same. Cooperation may make an oligopolistic market with a single homogenous product operate more imperfectly by concentrating market power in a few firms. With monopolistic competition, however, the market imperfection represented by $\eta<\infty$ is due to location, quality and other attributes rather than to the number of firms selling a homogenous product.

6. How important is the effect?

It would be perilous to develop extensive policy recommendations with such a stripped-down version of a model of energy disruptions.[15] Nevertheless, one might ask how significant an effect this might be.

In contrast to the oil import premium, this effect is linked more directly with total energy consumption than with imports.[16] Even an economy that provides all energy from domestic sources will experience the price shock resulting from disruptions elsewhere in the world. For this reason, one needs to consider how an economy will adjust to a disruption if it consumed less energy, not necessarily if it imported less energy. In the last scenario in Table 1, the energy requirements for producing the output were reduced by 10% below the previous cases. Both a non-disruption and a disruption case were simulated as before. This last column shows that the 50 percent energy price shock reduces output and welfare less with the lower energy use. Welfare declines by 3.88% rather than by 4.33% and total output declines by 1.79% rather than by 2.01%.

Another perspective on these estimates is to compare them with previous estimates of the oil import premium that was discussed at the paper's beginning. The Energy Modeling Forum (1981) compared the results of a number of different oil models and estimated this premium to be about $5 to $10 per barrel. Although those estimates were done some years ago, the lower end of this range appears reasonably consistent with

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[15] The model suggests that policies that reduced the energy price shock or that offset the price shock with reductions in other production costs (e.g., cuts in indirect sales tax or the payroll tax), as advocated by Mork and Hall (1982) and Solow (1980), might be effective.

[16] Reducing imports will improve the country's real income through the terms-of-trade effect. Lower import levels will not mitigate the externality discussed in this paper when the energy price shock is exogenous (as in this paper). However, if the disrupted oil price depends upon the disrupted region's share of world production, import reductions may lessen that market share and hence the oil price shock.

recent policy studies that have incorporated this effect (National Research Council 2001, p.86).

One needs to remember three important points about the import premium. First, its magnitude and even its existence depend upon a number of assumptions that were briefly referenced in this paper's footnote number three. Second, the premium measures the potential benefits from an action, or alternatively, how much additional costs should be incurred to reap those benefits. These benefits, on the margin, should match the dead-weight loss or costs of the implemented policy. Most importantly, the dead-weight losses are not forgotten or ignored. A premium of $5 per barrel means that the country should not adopt any policy that produces dead-weight losses in excess of $5 per barrel. And third, the premium should never to be tied to a particular policy option, like tariffs. One might argue for the premium concept but strongly prefer research and development incentives for replacing energy imports, stockpile releases, or macroeconomic policy over the adoption of an energy tariff.

In exactly the same spirit, the results reported in the last column of Table 1 can also be converted into a premium and expressed on a per barrel basis for comparison. When divided by the reduction in energy use due to the policy, the welfare gain is 56% of the reference energy price. Thus, if energy were priced privately at $26 per barrel and the risk of another shock happening over the next decade being one-third,[17] these calculations imply that a policy for reducing energy use would generate about $4.82 per

[17] In mid April 2002, crude oil futures were trading near $26 per barrel on the New York Merchantile Exchange. For the disruption probability, take a very simple example devoid of many possible complexities and ignoring the discounting of future cost streams. If the probability of a disruption in any year was 4%, the probability that there would be no disruption over the next decade would be $0.96^{10}= 0.66$. Thus, the probability of a shock sometime over the next decade would be about one third.

barrel of additional welfare distributed across all of the remaining firms. Of course, this policy would involve dead-weight losses. The estimated premium simply says that these losses should not exceed $4.82 per barrel at the margin.

7. Conclusion

Policymakers in major oil-consuming countries are primarily concerned with sudden disruptions that unexpectedly raise oil prices than they are with cartel-controlled oil prices. Suppose that the United States could totally replace its oil imports with domestic supplies including Alaskan resources.[18] If the pipeline transporting Alaskan oil to the lower 48 states failed or were sabotaged, many of the same concerns about Persian Gulf supplies would arise about these Alaskan supplies. Except for the terms-of-trade losses, oil disruptions pose problems whether the energy is imported or domestic. This paper provides a conceptual framework to recast the issue away from being an import problem and toward being a disruption problem.

When the economy is organized into numerous perfectly competitive industries, firms can probably adjust to the change in relative energy prices and develop options for mitigating the risks of future disruptions. When market power exists outside the energy sector, energy disruptions will produce larger output reductions than with perfect competition, because the economy begins at a position where prices exceed marginal cost. When that market power coexists with multiple firms, as with monopolistic competition, there is an additional problem of interfirm price effects. Since each firm has

[18] We ignore the costs of this import-displacement program, which would likely be significant.

a small effect on the aggregate price level, it can safely ignore this issue when setting its profit-maximizing price. However, when all firms adopt this strategy, they will push prices higher and reduce aggregate output. Although this pecuniary externality operates through the price system, the losses incurred by some firms are not offset by the gains made by other firms, as would be the case with perfect competition.

The paper has shown that firms reach a market equilibrium with output less than what would be socially desirable. Although this result is a useful one to establish, the approach assumes that firms correctly anticipate what other firms will do in the advent of an energy disruption. In the real world, disruptions create large uncertainties about what future energy prices will be and how different firms and industries will respond. A related and fruitful issue for future research would be to understand how these interfirm price effects materialize when firms have less perfect information about each other's behavior.

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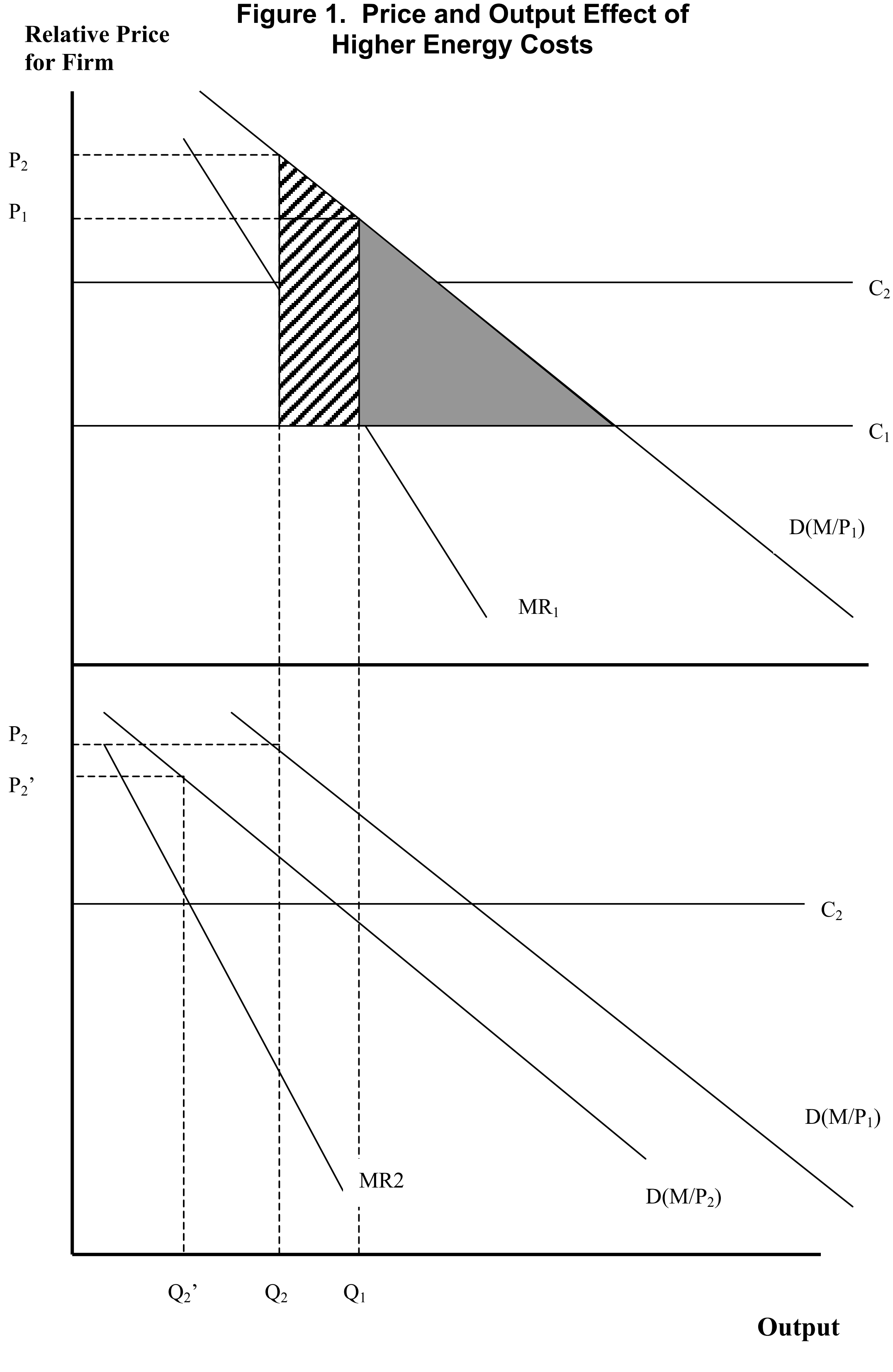
Figure 1. Price and Output Effect of Higher Energy Costs



Appendix A: Prices and Monetary Policy

The economy's aggregate price level is determined from its aggregate demand curve, Y=M/P. Using Eq. 11 to substitute for output, the price level is:

(A.1) $$P = \phi^{\gamma/(\gamma-1)} M / \left\{ [(\eta + \alpha - 1)/(\eta + \alpha)] - \lambda h \right\}^{1/(\gamma-1)}$$

This result confirms the neutrality of money with imperfect competition in this model. Expanded money supply does not influence output (Eq. 11). While the initial stimulus to demand raises prices (Eq. A.1), it fails to influence output and employment because wages rise by a similar amount. There is no net change in real wages.

In this model, authorities would not expand the nominal money supply because it would simply increase prices without augmenting output. The presence of imperfect competition does not make monetary policy any more effective than in the case of perfect competition. Monetary expansion will eventually lead to higher prices and wages but no additional output or welfare, unless there are other market imperfections that prevent firms from changing their prices. One such possibility would be menu costs, which include direct and opportunity costs as well as bad will among consumers.[19] If these conditions prevail, there could be an aggregate demand externality that would allow monetary authorities the opportunity to influence real output through their policy. Although the aggregate demand externality is an interesting possibility, it has some

[19] Mankiw (1985) and Blanchard and Kiyotaki (1987) discuss the externalities created by menu costs. This concept has appeared in some elementary texts, e.g., see Mankiw (1996). There is a broad literature on these types of externalities. For example, see Schultze (1985), Taylor (1987) and Ball *et al* (1988).

important limitations. For example, it cannot provide a major role for monetary intervention unless the supply of labor is much more wage elastic than has been found in many econometric studies.

Appendix B: Simulation Results

The percentage impacts reported in Table 1 are based upon simulating the equations explained in section IV. The average firm's quantities were multiplied by 10,000 firms to derive the total economy's quantities shown in Table B.1. Factor payments are spent completely on the output, as shown in Table B.2.

Table B.1: Simulated Economic Results With and Without Energy Price Shocks

				Shock w/	Low Energy	
	No Shock	Competition	Shock	Internalization	No Shock	Shock
energy shock	0%	0%	50%	50%	0%	50%
output	8585	9684	8412	8576	8619	8464
aggregate price	1.165	1.033	1.189	1.166	1.160	1.181
real wage	0.783	0.950	0.758	0.782	0.788	0.766
labor inputs	8585	9684	8412	8576	8619	8464
energy inputs	8585	9684	8412	8576	7757	7618
welfare	5819	5912	5703	5728	5868	5775
profits	1431	0	1402	1225	1436	1411
real wage bill	6725	9200	6379	6708	6794	6482
lost leisure	-2586	-3539	-2454	-2580	-2613	-2493

Table B.2: Summary of Output and Factor Payments

				Shock w/	Low Energy	
	No Shock	Competition	Shock	Internalization	No Shock	Shock
Final Demand	8585	9684	8412	8576	8619	8464
Real Wage Bill	6725	9200	6379	6708	6794	6482
Real Profits	1431	0	1402	1225	1436	1411
Real Energy Bill	429	484	631	643	388	571
Sum Payments	8585	9684	8412	8576	8619	8464