**OPEC's Incentives for Faster Output Growth**

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**Abstract**

This paper addresses the question of whether OPEC producers are likely to expand their oil output substantially over the next two decades – more than doubling in the Gulf countries by 2020. Such projections, made by the International Energy Agency (IEA) and the U.S. Department of Energy (DOE), are not based on behavioral analysis of Gulf countries' decisions, but are merely the residual demand for OPEC oil – the difference between projected world oil demand and Non-OPEC supply, given some assumed price-path.

I employ a simulation model to compare OPEC's payoffs from faster or slower output growth, under various parametric assumptions about the responsiveness of world oil demand and Non-OPEC supply to income and price changes. The payoffs to OPEC are relatively insensitive to faster output growth; aggressive output expansion yields slightly lower payoffs than just maintaining current market share. Analysis of intra-OPEC decisions – between the Core countries and the others – tells a story with a similar conclusion: these two groups are engaged in a constant-sum game.

Thus, the significant increases in OPEC output projected by IEA and DOE are implausible.

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## 1. Introduction

This paper addresses the question of whether OPEC oil output is likely to be expanded substantially over the next two decades, especially by the Gulf countries, as projected by the Energy Information Administration of the U.S. Department of Energy (DOE, 2002) and the International Energy Agency (IEA, 2002). It extends previous discussion of this issue in Gately (2001). I compare payoffs to OPEC from faster and slower output growth, under a variety of assumptions about OPEC output behavior.

The outline of the paper is as follows. Section 2 describes the assumptions of the model about oil demand and Non-OPEC supply, including possibly asymmetric responses to price increases and decreases. I address the uncertainty regarding the market's underlying parameter values by evaluating model results for 500 sets of assumptions, each case being defined by a particular value for all model parameters chosen from specified random distributions.

Section 3 evaluates the model projections to 2020 for price, world oil demand, Non-OPEC supply and OPEC output – under five alternative assumptions about OPEC's market-share targets: hold its share of the world oil market constant (at 37%), or let its share grow linearly to one of several targets by 2020 – 42%, 47%, 52% – or let it decline linearly to 32% by 2020. For the various market-share targets, I present the distribution of price and quantity results in 2010 and 2020 for all 500 cases evaluated, as well as the values of Discounted Export Profits.

Section 4 examines the intra-OPEC choices made between slower or faster output growth. I focus on two sub-groups:

- The "Core": Saudi Arabia, Kuwait, and UAE
- The other "Non-Core" members of OPEC: Iran, Iraq, Qatar, Libya, Algeria, Nigeria, Indonesia and Venezuela.

For the Non-Core I examine two alternative assumptions: that they increase their oil output at a given annual rate, either 1% or 3%. For the Core I also consider two alternatives: that they expand their output to achieve a target share of the world oil market – either a constant share (at 15%, their current share) or a share that grows linearly to 20% by year 2020. For each of the four combinations for Core and Non-Core output growth (slow/slow, slow/fast, fast/slow, fast/fast), I summarize the price and quantity results for 2010 and 2020 for all 500 cases examined, and the groups' respective Discounted Export Profits.

Section 5 summarizes my conclusions about the likelihood of faster output growth, especially in comparison with projections by DOE and IEA.

## 2. The Model

Using an Excel spreadsheet model of the world oil market, calibrated to data from DOE, I examine a variety of behaviors for OPEC[1]. The specification of the model, described previously in Gately(1995), has now been modified to allow for the possibility of a smaller response to price decreases than to price increases. In addition, the model now allows for uncertainty about parametric values for price and income elasticities of demand and Non-OPEC supply.

The model was specified to allow for a response to price increases and decreases that could be *asymmetric*, in three dimensions – the price responsiveness of Non-OPEC oil

[1] There is a substantial literature of such models of OPEC behavior; for surveys, see Gately (1984) and Cremer and Salehi-Isfahani (1991). There have been two major studies of world oil models (including earlier versions of this model) conducted by the Energy Modeling Forum of Stanford University: see Energy Modeling Forum (1982, 1991). There have been several models that explicitly optimize for OPEC behavior, such as those of Pindyck (1978), Salant (1982), Marquez (1984), Marquez and Pauly (1986), and Rauscher (1989); such models have been criticized for ignoring the problem of parametric uncertainty: see Gately (1984, 1995).

supply[2], the price responsiveness of oil demand[3], and the feedback of oil prices onto GDP growth rates[4]. This asymmetry is important for analyzing the market response for scenarios in which OPEC would increase its output rapidly, lowering the price – such as those projected by the IEA and DOE. A standard price-symmetric model will overstate the benefits to OPEC from lower prices, because it will overstate each of the following results of lower prices: the amount of Non-OPEC supply that would be deterred, the increase in world oil demand that results directly from lower price, and the increase in world economic growth that would result from lower oil prices and indirectly increase world oil demand.

The model's variables and equation specification are described next, followed by a listing of the distribution of uncertain parameter value of the model such as the elasticities.

**List of Variables:**

- $P_t$ Real Price of Crude Oil in year t (2000 $ per barrel).
  The following used in the Demand equation Specification
  - $\log P_{incr,\,t}$ logarithm of Price Increases, cumulative to year t
  - $\log P_{decr.,\,t}$ logarithm of Price Decreases, cumulative to year t
- $Y_t$ Real Income, year t, for given demand region (Billions 2000$)
- $D_t$ Demand for Oil in year t (million barrels per day: mbd)
- $S_t$ Non-OPEC Supply of Oil in year t (mbd)
  The following are used in the Non-OPEC equation specification:
  - $P_{t\ Ref.}$ Reference-case price-path: $22.50, constant in real terms 2002-2020
  - $S_{t\ Ref.}$ Reference case Non-OPEC Supply projection, given the Reference-case price-path
- $X_t$ OPEC Production of Oil (mbd)

Demand Regions: USA, Japan, OECD Europe, Other OECD; Former Soviet Union & Eastern Europe, China, Other Developing Asia, Middle East, Other Developing Countries

Non-OPEC Supply Regions: USA, Canada, Mexico, OECD Europe, Other OECD; China, Former Soviet Union, Eastern Europe, Central & South America, Pacific Rim, Other Developing Countries

OPEC: Saudi Arabia, Kuwait, UAE, Iran, Iraq, Qatar, Algeria, Libya, Nigeria, Venezuela, Indonesia

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[2] See Appendix A for a discussion of the asymmetric price-responsiveness of oil supply. See Moroney (1997) and Moroney and Berg (1999).

[3] There have been several articles over the past decade on the asymmetric response of oil demand to increases and decreases in price: see Gately (1993), Dargay-Gately (1994), and Gately-Huntington (2002).

[4] See articles by Mork (1989), Mork, Olsen, and Mysen (1994), and Huntington (1998 ).

**World Oil Demand**

Oil demand is calculated separately for transportation oil and non-transportation oil, in each region, using an equation and coefficient estimates from Gately and Huntington (2002). Demand adjustment to income changes is assumed to occur within the year, and to respond symmetrically to income increases and decreases. Demand adjustment to price changes follows a lagged-adjustment process, and may respond more to price increases than to price decreases.

$$\log D_t = k_1 + \theta_p \log D_{t-1} + \beta_i \log P_{incr,\,t} + \beta_d \log P_{decr.,\,t} + \gamma \log Y_t - \theta_p \gamma \log Y_{t-1} \qquad (1)$$

where $\theta_p$ is the lagged adjustment coefficient for price
$\theta_p = 0.9$ for transportation oil demand
$\theta_p = 0.8$ for non-transportation oil demand (faster adjustment) ;
and $\beta_d = \alpha_1 \beta_i$ reflects the possibility of asymmetric response between price increases and decreases; the fraction $\alpha_1$ is assumed to be uniformly distributed from 0.6 to 1.0, with the upper bound 1.0 being symmetric response; in the median case $\alpha_1 = 0.8$

The price elasticity of transportation oil demand with respect to the price of crude oil[5] is assumed to have a long-run elasticity for price increases that is uniformly distributed between -0.2 and -0.4; the price elasticity for non-transportation oil is twice as large. In Non-OECD regions the price elasticities are only one-third as large as in the OECD. The income elasticity of oil demand in the OECD regions is assumed to be normally distributed with mean of 0.55 and standard deviation 0.05, and in the Non-OECD regions having a mean of 1.0 and standard deviation 0.05. These estimates are based upon econometric estimation in Gately and Huntington (2002).

**Non-OPEC Supply**

Specifications of Non-OPEC supply that are analytically based only on price and other economic variables are difficult to construct[6], and constrained by data limitations for regions outside the US. Hence, as in Gately (1995, 2001), my specification is based upon the DOE Reference Case projections of Non-OPEC supply[7] growing (at a constant "Reference Case" price of $P_{t\,Ref.} = \$22.50$) from about 47 mbd in 2002 to about 61 mbd by 2020. For prices above or below the Reference Case price of $22.50, I use the following specification:

for $P_t \geq P_{t\,Ref.}$

$$S_t = S_{t\,Ref.} (S_{t-1}/S_{t-1\,Ref.})^{1-a} (P_t/P_{t\,Ref.})^a \qquad (2)$$

for $P_t < P_{t\,Ref}$

$$S_t = S_{t\,Ref.} (S_{t-1}/S_{t-1\,Ref.})^{1-b} (P_t/P_{t\,Ref.})^b \qquad \text{where } b = \alpha_2 a.$$

The short-run price-elasticity parameter, *a*, is assumed to be uniformly distributed between 0.03 and 0.05. The long-run price-responsiveness of Non-OPEC oil supply (by 2020) varies between 0.15 and 0.58. The parameter $\alpha_2$ measures the degree of asymmetry in Non-OPEC supply response for prices above or below the Reference Case price[8]; it is assumed uniformly distributed from 0.3 to 1.0, with the upper bound 1.0 being symmetric

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[5] Price elasticity with respect to the delivered price of oil products could be 50% higher, because product prices are higher than crude oil prices. For surveys of oil demand elasticities, see Dahl (1993), (1995), and the discussion of the literature that is referenced in Gately and Huntington (2002). Parameter distributions assumed to be uniform rather than normal reflect a greater degree of uncertainty.

[6] The best examples – but limited to the USA – are Moroney (1997) and Moroney and Berg (1999). For surveys of this literature on Non-OPEC supply models and elasticities, see Walls (1992), Dahl and Duggan (1998), and Watkins and Streifel (1998).

[7] See DOE (2002), Table 10. The DOE Reference Case price is assumed to increase very slowly in real terms, at about ½% annually.

[8] I ignore the possibly asymmetric supply effects of price being above the Reference Case price but decreasing, or below the Reference Case price but increasing.

response. See Appendix A for a discussion of asymmetric price-responsiveness of Non-OPEC supply. Uncertainty about discoveries and the rate of technological improvement is reflected by a randomly varying scalar which increases the variable $S_{t\ Ref.}$ faster or slower than in the DOE Reference Case. Such variation is normally distributed around the DOE Reference Case projections (61 mbd by 2020), with a standard deviation of 5%. Thus, at the Reference case price, Non-OPEC supply could be 64 mbd by 2020 with a plus-one standard-deviation value for this scalar, or 58 mbd with a comparably smaller value. This specification was used in Gately (1995, 2001); the specification and parametric values are judgmentally based.

**Income Growth Rate**

I assume the DOE Reference Case growth rates for GDP, for each of their demand regions[9]. For prices above or below the Reference Case price of $22.50, I assume that the income growth rate will be affected as follows:

$$g_t = g_{t\ Ref.} \left( P_t / P_{t\ Ref.} \right)^{-.05} - \alpha_3\ 0.03\ (P_t - P_{t-1})) \qquad (3)$$

where $\alpha_3 = 1$ for $P_t \geq P_{t\ Ref.}$ . For price decreases $\alpha_3$, the asymmetry constant is an uncertain parameter that is uniformly distributed between 0.5 and 1.0. Except for the possible asymmetry, this is the same specification as used in Gately (1995) and in several models that participated in Energy Modeling Forum (1982), (1991). The asymmetric response of income growth rates to increases and decreases in oil prices is discussed in Mork (1989), Mork, Olsen, and Mysen (1994), and Huntington (1998).

**Model Solution**

The simulation model can be solved in different ways. Given a price-path, the model calculates world oil demand, Non-OPEC supply, and the residual demand for OPEC oil; see Figures 1 and 2 below, which evaluate three constant-price paths. Alternatively, given some OPEC output-path, the model can solve for the market-clearing price-path at which world oil demand minus Non-OPEC supply is exactly equal to the given OPEC output-path. In Gately (1995), various OPEC output-paths were evaluated, each growing in proportion to the rate of world economic growth: as fast, half as fast, etc. In the target-market-share paths evaluated below, the model finds the market-clearing price-path at which the ratio of the demand for OPEC oil (world oil demand minus Non-OPEC supply) to total world oil demand is equal to the target market-share for OPEC. Similarly, in Section 4 below, I evaluate target market-share strategies for OPEC's "Core" group of countries, by finding the market-clearing price such that the ratio of the demand for the Core's oil (world demand minus Non-OPEC supply minus Non-Core output) to total world oil demand is equal to the target market-share for the Core.

**Illustrative Parameter Values for the Model**

In order to provide the reader with a sense of how the model's price-responsiveness depends upon the parameter values assumed, some illustrative sets of parameter values are shown in Table 1:

- symmetric price-responsiveness and relatively price-elastic
- median values for parameters
- asymmetric price-responsiveness and price-inelastic

The first set (symmetric and relatively price-elastic) is the most favorable to faster increases in OPEC output and lower prices. The third set (asymmetric and price-inelastic) is the least favorable to faster increases in OPEC output and lower prices.[10]

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[9] See DOE (2002), Table A3. Average annual Income growth rates are 2.7% for the OECD, 4.5% for Eastern Europe and the Former Soviet Union, 5% for Developing Countries, and 3.2% for the world.

[10] DOE (2002) assumes parameter values that are very price-inelastic yet it projects rapid growth in OPEC output. As was argued in Gately (2001), the DOE model is internally inconsistent.

The demand and supply results for each of these three sets of parameter values are plotted in Figures 1 and 2, for three prices-paths (in 2000 $):

- constant price, $22.50, for 2002-2020
- price increase to $30 in 2003, remaining constant to 2020
- price decrease to $15 in 2003, remaining constant to 2020

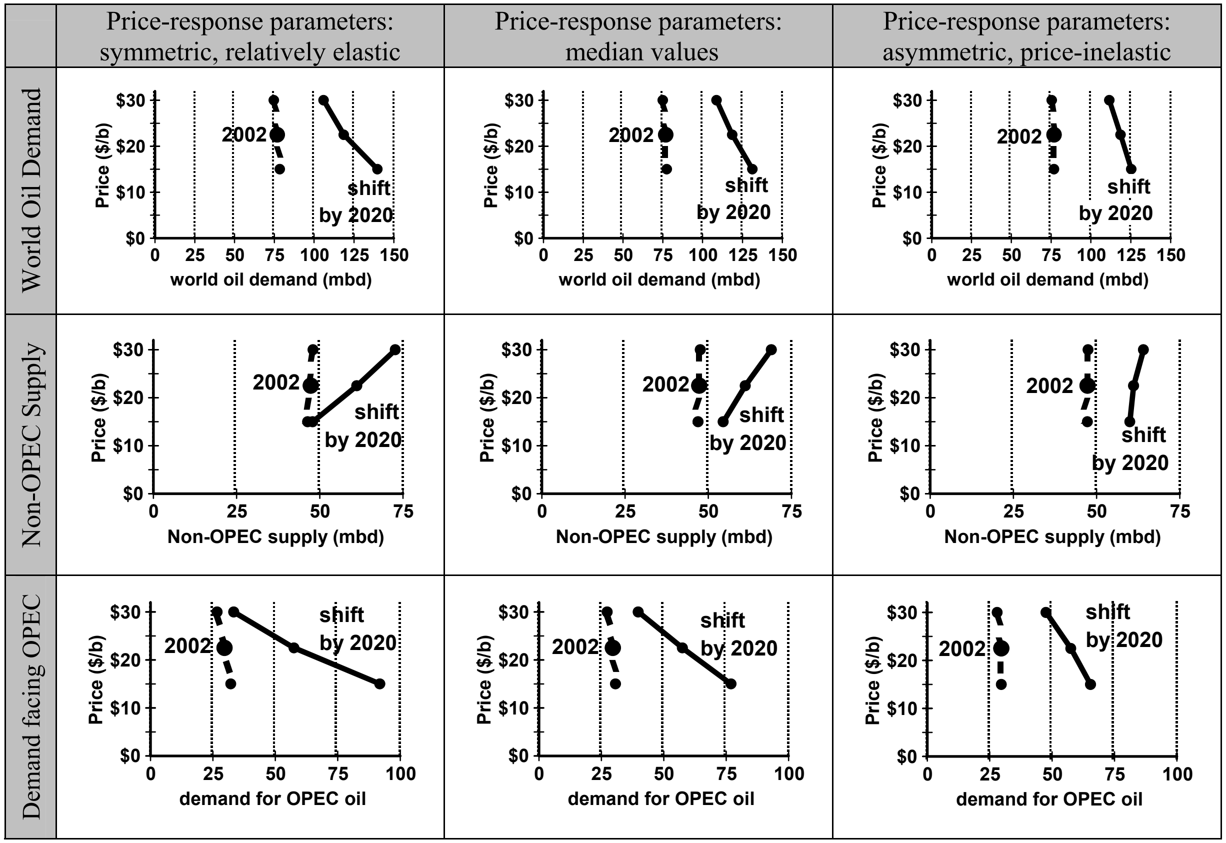
The smaller the price elasticities and the greater the degree of asymmetric price-responsiveness of demand, income growth, and Non-OPEC supply, the less attractive for OPEC will be strategies that would increase output faster and suppress price – and the more cautious that OPEC ought to be about unsustainable price increases – because their effects cannot be reversed easily.

Figure 1 depicts stylized short-run and long-run curves for world oil demand, Non-OPEC supply, and the resulting demand for OPEC oil in 2002, 2003 and 2020. The dashed lines indicate the short-run response, in year 2003, to a price change from its 2002 level ($22.50). The solid lines indicate the long-run response by 2020 (assuming a constant price for 2003-20 at either $15, $22.50, or $30), as the world oil demand curve shifts out due to income growth, and the Non-OPEC supply curve shifts out because of exploration and improved technology. Note that, in order to simplify the graphing, for intermediate price-levels (say between $22.50 and $30) the point estimates for $22.50 and $30 were connected with a line – even though the demand and supply specifications are not linear.

Table 1. Price response parameters: illustrative cases

| | Symmetric and relatively price-elastic | Median values | Aysmmetric and price-inelastic |
|---|---|---|---|
| Oil Demand: long-run elasticity with respect to price increases:<br>Transportation Oil<br>Non-transportation Oil | -0.4<br>-0.8 | -0.3<br>-0.6 | -0.2<br>-0.4 |
| Non-OPEC Supply: long-run elasticity with respect to price increases | 0.58 | 0.365 | 0.15 |
| Symmetry coefficients for price increases and decreases:<br>Demand<br>Non-OPEC Supply<br>Income Growth | 1.0<br>1.0<br>1.0 | 0.8<br>0.63<br>0.75 | 0.6<br>0.25<br>0.5 |

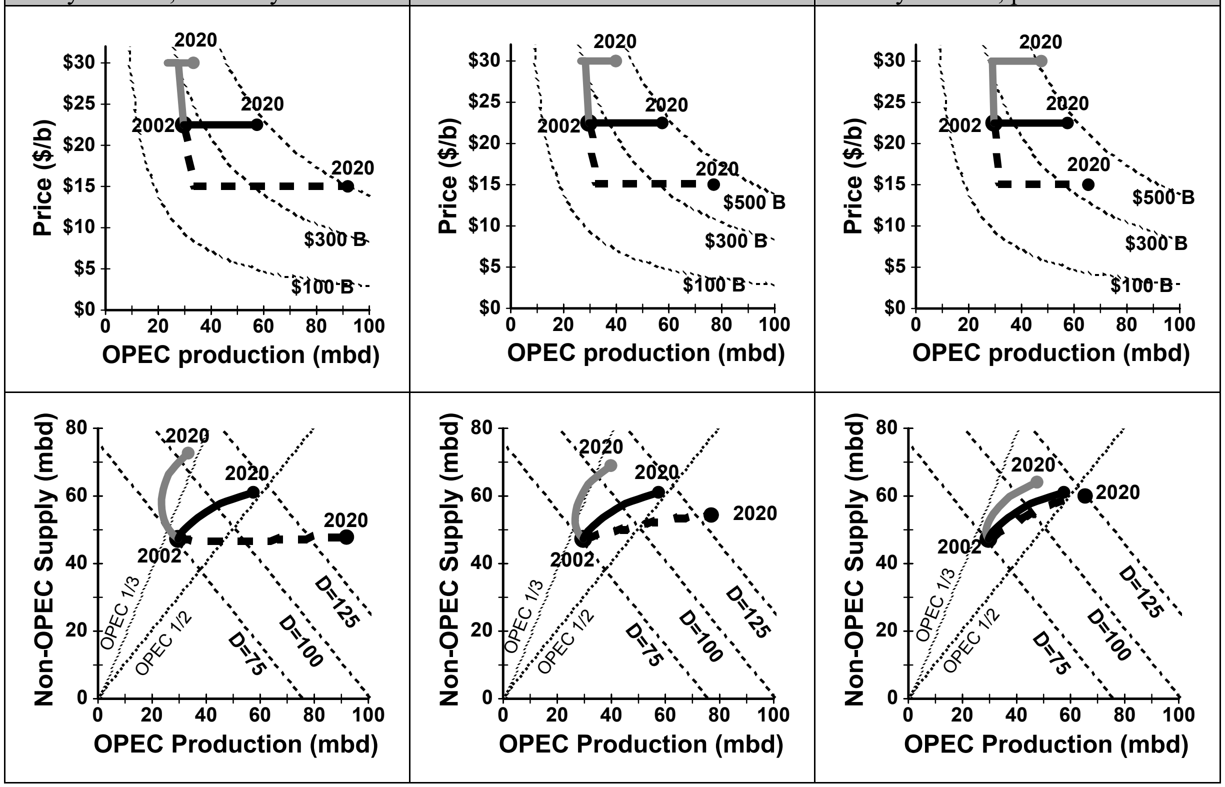
Figure 1. Sensitivity of demand and supply in the short run (2003) and long run (2020, shifted by income growth and Non-OPEC supply growth), for alternative price-response parameter values (columns): symmetric and relatively price-elastic; median; asymmetric and price-inelastic.




Legend: Dashed lines: short-run curves. Solid lines: long-run curves

Figure 2. Demand for (and production of) OPEC oil and Non-OPEC supply 2002-2020, for three alternative price paths starting at $22.50 in 2002 then constant for 2003-2020, respectively at $22.50, $30, or $15 – for three alternative price-response parameter values (columns): symmetric and relatively price-elastic; median; asymmetric and price-inelastic

| Price-response parameters: symmetric, relatively elastic | Price-response parameters: median values | Price-response parameters: asymmetric, price-inelastic |
|---|---|---|




Legend: Solid, dark curves: $22.50 price-path. Solid, grey curves: $30 price-path. Dashed curves: $15 price-path.

Figure 2 presents the 2002-2020 time-paths of demand and supply for each of the 3 price-paths, for each of the three sets of parameter values. The upper graphs plot price and the demand for OPEC oil (= OPEC production) from 2002-2020 that would correspond to three alternative price-paths in which price remains constant from 2003-2020: $22.50 (solid, dark line), $15 (dashed line), and $30 (gray, solid line). In the background are three (dotted) iso-revenue curves for OPEC: at $100, $300, $500 billion/year (2000$). The lower graphs plot the levels of Non-OPEC supply and OPEC production for 2002-2020 that correspond to these three price-paths. In the background are three downward-sloping (dotted) iso-demand-lines for world oil demand: at 75 mbd, 100 mbd, 125 mbd, respectively (from left to right). Also in the lower graphs are two (dotted) iso-OPEC-share rays from the origin, indicating constant levels of OPEC share of the world oil market, at one-third and one-half, respectively (clockwise).

## 3. Results for Demand, Supply, Price and Revenue – across OPEC Market-Share Targets

This section shows the model results for five alternative paths for OPEC's share of the world oil market: maintaining its current share (37%), letting its share decline linearly to 32% by 2020, or letting its share increase linearly to (respectively) 42%, 47%, or 52% by 2020. Each of these 5 paths is evaluated for 500 sets of parameter values; each set has different values for each of the uncertain parameters described in the previous section. For a given set of parameter values and a given path for OPEC market share, the model solves for the market-clearing price in each year through 2020 at which world demand for OPEC oil is exactly equal to the path's market-share target for that year. Shown in Table 2 are the median values for the model's projections for 2010 and 2020, together with projections by DOE and IEA.

Table 2. Median values of model projections for 2010 and 2020 for five OPEC market-share targets for 2020, and comparisons with DOE and IEA projections

| | Price (2000 $/b) | Demand (mbd) | Non-OPEC Supply (mbd) | OPEC Output (mbd) | OPEC market share | OPEC Revenue (Billions/yr. 2000 $) |
|---|---|---|---|---|---|---|
| | **year 2010 projections:** | | | | | |
| **DOE: Reference Case** | $23.36 | 95.7 | 53.6 | 42.1 | 44% | $359 |
| High Price Case | $30.01 | 92.4 | 58.1 | 34.3 | 37% | $376 |
| Low Price Case | $17.64 | 99.2 | 52.1 | 47.1 | 47% | $303 |
| **IEA: Reference Case** | $21.00 | 88.8 | 50.7 | 38.1 | 43% | $292 |
| **Model Projections:** | | | | | | |
| if OPEC market-share target for 2020: | | | | | | |
| 32% | $28.56 | 85.7 | 55.8 | 29.9 | 35% | $312 |
| 37% (current) | $25.94 | 87.2 | 54.9 | 32.4 | 37% | $306 |
| 42% | $23.45 | 88.7 | 54.0 | 34.7 | 39% | $297 |
| 47% | $21.13 | 90.4 | 53.3 | 37.1 | 41% | $286 |
| 52% | $18.81 | 92.1 | 52.7 | 39.4 | 43% | $271 |
| | **year 2020 projections:** | | | | | |
| **DOE: Reference Case** | $24.68 | 118.3 | 61.1 | 57.2 | 48% | $515 |
| High Price Case | $30.58 | 113.8 | 69.2 | 45.6 | 40% | $509 |
| Low Price Case | $17.64 | 124.9 | 58.7 | 66.2 | 53% | $426 |
| **IEA: Reference Case** | $25.00 | 104.0 | 49.6 | 54.4 | 52% | $497 |
| **Model Projections:** | | | | | | |
| if OPEC market-share target for 2020: | | | | | | |
| 32% | $41.15 | 103.3 | 70.1 | 33.2 | 32% | $498 |
| 37% (current) | $34.64 | 106.9 | 67.3 | 39.7 | 37% | $502 |
| 42% | $28.00 | 111.1 | 64.3 | 46.8 | 42% | $478 |
| 47% | $21.32 | 116.0 | 61.4 | 54.6 | 47% | $425 |
| 52% | $14.55 | 122.0 | 58.4 | 63.6 | 52% | $338 |

Notes: OPEC Revenue is calculated here as the product of price and output; this implies that internal OPEC consumption yields the same price as exports. IEA supply projections for OPEC and Non-OPEC include prorated amounts of processing gains.

DOE and IEA both project rapid growth in OPEC output and market share. IEA projects much less Non-OPEC supply and world oil demand, in comparison with DOE. IEA projects Non-OPEC supply in 2020 to be lower than in 2010, while DOE projects continuing growth. However, both have Reference Case projections of OPEC share of the world oil market increasing rapidly for two decades, to about one-half of the world market by the year 2020. Such rapid increases in OPEC market share are among the targets that are evaluated by my model. As shown below, the faster the growth in OPEC output and market share, the lower the Discounted Export Profits.

Figure 3 plots projections for the entire set of 500 cases, for years 2010 and 2020 in the left and right columns respectively, for four of the market-share paths; the 52% share path was not plotted due to space constraints. The higher OPEC's market share, the lower the market-clearing price – although there is substantial price-dispersion across the 500 cases by 2020, especially if OPEC does not increases its market share rapidly. The location of price and OPEC output relative to the iso-revenue curves indicates that OPEC generally gets lower revenue the faster that it increases its market share.

The full distribution is plotted in order to provide an understanding of the dispersion of projections for prices and quantities that result from relatively small changes in the underlying parameter values of this model. Different readers will have different beliefs about the "true" parameter values, and about likely future outcomes. Plotting the full distribution also illustrates the impossibility of finding a *single* optimal price-path or output-path for OPEC, due to the sensitivity of outcomes to parametric assumptions whose true values are not knowable.

The three DOE cases (Table 2) fall within the clusters, for the higher OPEC market-share paths. The DOE projections assume very little price-responsiveness for world oil demand and Non-OPEC supply , at the extreme of the parametric range assumed here – see Gately (2001) – so that the DOE model would yield relatively high prices for slow output growth from OPEC and relatively low prices for fast output growth.

The IEA Reference Case would be near the left edge of the clusters, for the highest OPEC market-share path. Its Non-OPEC supply projections are relatively low – at most 15% higher in 2020 than in 2000, in contrast to DOE's Reference Case projection of 30% higher. Similarly low are its demand projections, especially for Developing Asia excluding China. IEA's implied income elasticities of oil demand are about 0.75 for that region (significantly lower than my model's 1.0 income elasticity for that region). Assumed GDP growth rates are also lower, for all regions, than what DOE and my model assume. Detailed analysis of the IEA projections is not possible, however, because their model's implied *price*-elasticities cannot be inferred, given that they publish only Reference Case projections (unlike DOE which also publishes High-Price and Low-Price Cases).

Figure 3. Model projections for 2010 and 2020, of price (2000 $/b), demand and supply (mbd), with three iso-revenue curves ($100, $300, $500: Billions/yr., 2000 $), for four market-share targets for OPEC: 500 cases simulated. Clusters, from left to right, are OPEC production, Non-OPEC Supply, World Demand.

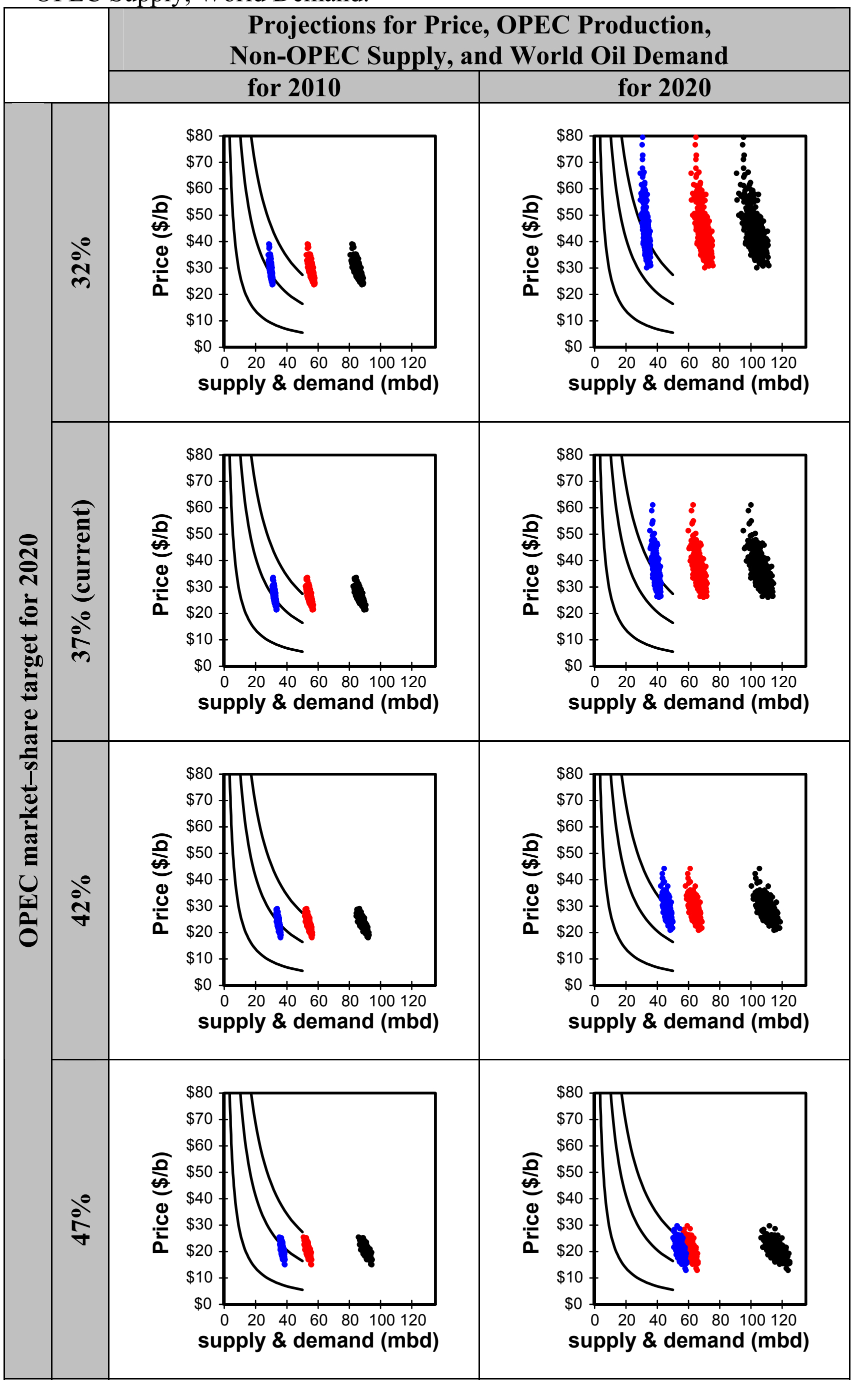


Figure 4. Median values of Discounted OPEC Export Profits (Billions 2000 $) for five OPEC market-share targets, for discount rate r = 2%, 5%, or 10%

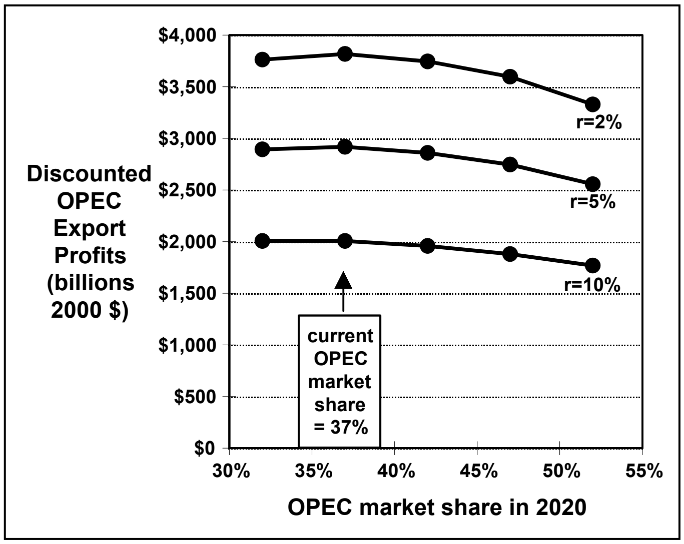



Figure 4 plots the median values for OPEC's Discounted Export Profits[11] for five different market-share targets, using a discount rate[12] *r* of either 2%, 5% or 10%. For any of the three discount rates, OPEC's median payoff is highest – by a slight amount – if it just maintains its market share at the current level of 37% of the world market. The more it increases its market share from 37%, the lower will be its payoff. If instead OPEC were to allow its market share to decline slowly, to 32% by 2020, it would do just about as well as if it were to keep its market share constant.

The rapid increases in OPEC market-share that are projected by DOE (48% by 2020) and IEA (52% by 2020) are likely to be contrary to OPEC's own best interests. If OPEC were to increase its market share as rapidly as projected by DOE and IEA, then its payoff would be lower than if OPEC were to just maintain its market share at 37%.

[11] As in Gately (1995, 2001), I focus on Export Profits rather than Total Profits; that is, I ignore oil revenue from internal OPEC consumption, which is often subsidized and for which revenue data are not available. I also ignore the opportunity cost of the oil reserves extracted in 2003-2020; had these costs be included, the payoffs would have been reduced (slightly, given their discounted revenue value in the distant future) in proportion to the rate of output growth.

[12] These are real discount rates; all financial variables are measured in real terms (2000 $). Thus we ignore the effect of oil price increases on general inflation rates.

## 4. The Effects of Intra-OPEC Output Expansion Decisions upon results for Demand, Supply, Price & Revenue

Given that OPEC does not act collectively and has difficulty reaching and enforcing agreements among its members, it is important to understand how output-expansion decisions might be made by smaller groups within OPEC. I assume that OPEC consists of two groups of countries:

- The “Core” members: Saudi Arabia, Kuwait, and UAE
- The “Non-Core” members: Iran, Iraq, Qatar, Libya, Algeria, Nigeria, Indonesia and Venezuela.

The Core countries have often acted in concert and are often considered to be the price-setting, “swing” producers within OPEC; they are distinguished by abundant oil reserves and relatively small populations. The Non-Core members generally have larger populations and relatively smaller oil reserves, and are more heterogeneous than the Core.

I assume that the Core and the Non-Core each have a choice between slower or faster output growth. The Non-Core members of OPEC could expand their output level at a constant annual rate, assumed to be either 1% or 3%. The Core chooses between two market-share targets: to control its output level so that it achieves either a constant fraction of 15% of world demand for each year 2002-2020, or a share of world demand that grows linearly, from 15% in 2002 to 20% by 2020. I evaluate the model results under the resulting four combinations of Core and Non-Core choices for output growth: slow-slow, slow-fast, fast-slow, and fast-fast – for 500 cases being simulated. The combination that is closest to the DOE and IEA projections is “fast-fast” (3% growth for Non-OPEC and increasing Core share), but the DOE and IEA projections for OPEC output growth are even higher: from 3.5% to 3.7% annually.

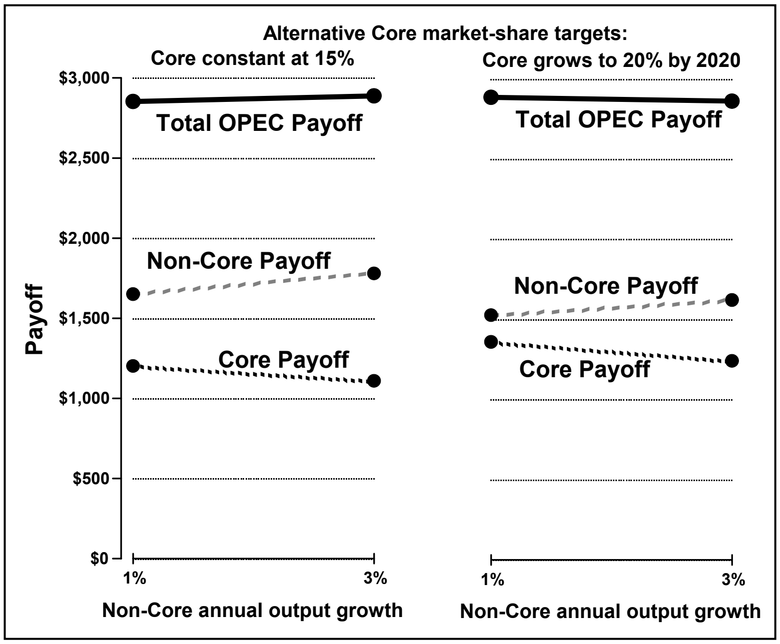
Table 3 presents the median projections of price, quantities, and revenue for 2010 and 2020. Median values for Discounted Export Profits are shown in Figure 5, using a discount rate of 5%; results are qualitatively similar for discount rates of 2% or 10%.

Table 3. Median values of model projections for 2010 and 2020 given alternative output-growth strategies for Core & Non-Core

| Non-Core output growth rate annually | Core market share target | Price (2000 $/b) | Demand (mbd) | Non-OPEC Supply (mbd) | OPEC Output (mbd) | | | OPEC market share | OPEC Revenue (Billions/yr. 2000 $) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Core | Non-Core | Total | | Core | Non-Core | Total |
| | | **year 2010 results:** | | | | | | | | | |
| 1% | 15% constant | $26.16 | 87.6 | 55.6 | 13.1 | 18.9 | 32.0 | 37% | $126 | $180 | $306 |
| 1% | 20% by 2020 | $24.41 | 88.7 | 54.5 | 15.3 | 18.9 | 34.2 | 39% | $136 | $168 | $304 |
| 3% | 15% constant | $23.84 | 89.5 | 54.0 | 13.4 | 22.1 | 35.5 | 40% | $117 | $192 | $309 |
| 3% | 20% by 2020 | $22.12 | 90.8 | 53.1 | 15.6 | 22.1 | 37.7 | 42% | $126 | $178 | $304 |
| | | **year 2020 results:** | | | | | | | | | |
| 1% | 15% constant | $34.32 | 107.7 | 70.9 | 16.2 | 20.6 | 36.8 | 34% | $202 | $258 | $461 |
| 1% | 20% by 2020 | $30.91 | 110.3 | 67.6 | 22.1 | 20.6 | 42.7 | 39% | $249 | $233 | $482 |
| 3% | 15% constant | $29.53 | 111.8 | 66.3 | 16.8 | 28.7 | 45.4 | 41% | $181 | $309 | $490 |
| 3% | 20% by 2020 | $26.32 | 114.8 | 63.1 | 23.0 | 28.7 | 51.6 | 45% | $221 | $275 | $496 |

Figure 5. Median Payoffs to Core, Non-Core, & Total OPEC (Discounted Export Profits, r=5%, in Billions 2000 $) corresponding to output-growth behavior of Core and Non-Core.

| | | Annual output growth rate for Non-Core: 1% | Annual output growth rate for Non-Core: 3% |
|---|---|---|---|
| Core market share target | constant at 15% | Core: $1,202<br>Non-Core: $1,651<br>OPEC: $2,853 | Core: $1,109<br>Non-Core: $1,780<br>OPEC: $2,888 |
| | growing to 20% by 2020 | Core: $1,360<br>Non-Core: $1,528<br>OPEC: $2,887 | Core: $1,242<br>Non-Core: $1,622<br>OPEC: $2,864 |



A natural interpretation of these results is that these two groups within OPEC are engaged in a constant-sum game.[13] Total OPEC payoffs will be virtually unchanged whether both groups expand output slower or faster, or whether one expands faster and the other expands slower. Each group has some incentive to expand its own output faster if the other group would expand output slowly. But if each group expects the other to match its output growth increases – with neither benefiting from faster output growth – then faster output growth from both is unlikely.

Of course, others may disagree. Mitchell *et al.* (2001) argues that competitive pressures within the Gulf will lead to rapid growth in capacity and output, an outcome similar to those of DOE and IEA. James Smith[14] has argued that faster output growth by the Core could suppress price enough that it could deter output growth elsewhere in OPEC. Moreover, parameter values with substantially greater price-responsiveness of world oil demand and Non-OPEC supply – especially for lower prices – could make the demand for OPEC oil much more price-responsive than assumed here. Hence rapid increases in OPEC output would not depress price so much, and OPEC revenue could rise substantially, giving OPEC and its key producers the necessary incentive to expand output rapidly.

## 5. Conclusions

The issue is whether OPEC countries would have sufficient incentive to increase their production as rapidly as projected by DOE and IEA – not whether the demand for OPEC oil will rise so rapidly. Of course, rapid increases in OPEC output would increase OPEC's revenues and profits. However, the key question is whether slower increases in OPEC output would increase their profits even more. We can expect such rapid output increases from OPEC and its key producers only if they would benefit more from that strategy than from slower increases in output.

With the assumptions made in this paper, if OPEC acts collectively then it has no incentive to increase its output as rapidly as DOE and IEA project, because faster increases in output would be more than offset by lower prices. The faster it increases its market share above its current level (37%), the lower will be its likely payoff. If OPEC were to increase its market share as rapidly as projected by DOE and IEA, then its payoff would be lower than if OPEC had just maintained its market share. OPEC would have substantial incentives for increasing its production as rapidly as projected only if demand and Non-OPEC supply were significantly more price-responsive than is assumed here.

Of course, OPEC's ability to coordinate its pricing or output strategy is limited; coordinated planning seems very unlikely. To focus upon the output-expansion incentives for smaller groups within OPEC, I examined two sub-groups – the Core and the Non-Core – and I explored the implications of slower or faster output growth for each group. The results indicate that, in effect, these two groups are engaged in a constant-sum game. Total OPEC payoffs will be virtually unchanged whether both groups expand output slower or faster, or whether one expands faster and the other expands slower. Each group has some incentive to expand its own output faster if the other group would expand output slowly. But if each group expects the other to match its output growth – with

[13] It is *at best* a constant-sum game, if the groups pursue reasonable strategies. If instead OPEC attempts a repeat of the 1978-86 fiasco, with abrupt price increases that were unsustainable, their payoffs could be significantly lower.

[14] Private communication.

neither benefiting from faster output growth – then faster output growth from both is unlikely.

We should not expect the significant increases in OPEC output that are projected by DOE and IEA – and certainly not a *doubling* of capacity from levels that haven't changed substantially in the three decades since the OPEC countries took control of their oil from the international oil companies. OPEC's production will increase substantially only if one or more countries within OPEC believe that they can achieve a sustainable increase in their share of OPEC production.

The obstacles to aggressive expansion of capacity within OPEC are substantial. More likely would be a cautious approach to capacity expansion, with only moderate growth, at most 2% annually – much less than the 3.5% to 3.7% annual growth assumed by DOE and IEA. Such decisions could be motivated by various political and economic arguments: competing claims on government budgets that compete with investments in capacity expansion; unwillingness to allow participation by foreign oil companies; and conservation concerns about too-rapid exhaustion of oil reserves. One could even imagine statements of concern about global warming, and the willingness of the oil producing countries "to do their part" – especially if they believe there would be no profit penalty from slower output growth.

## Appendix A

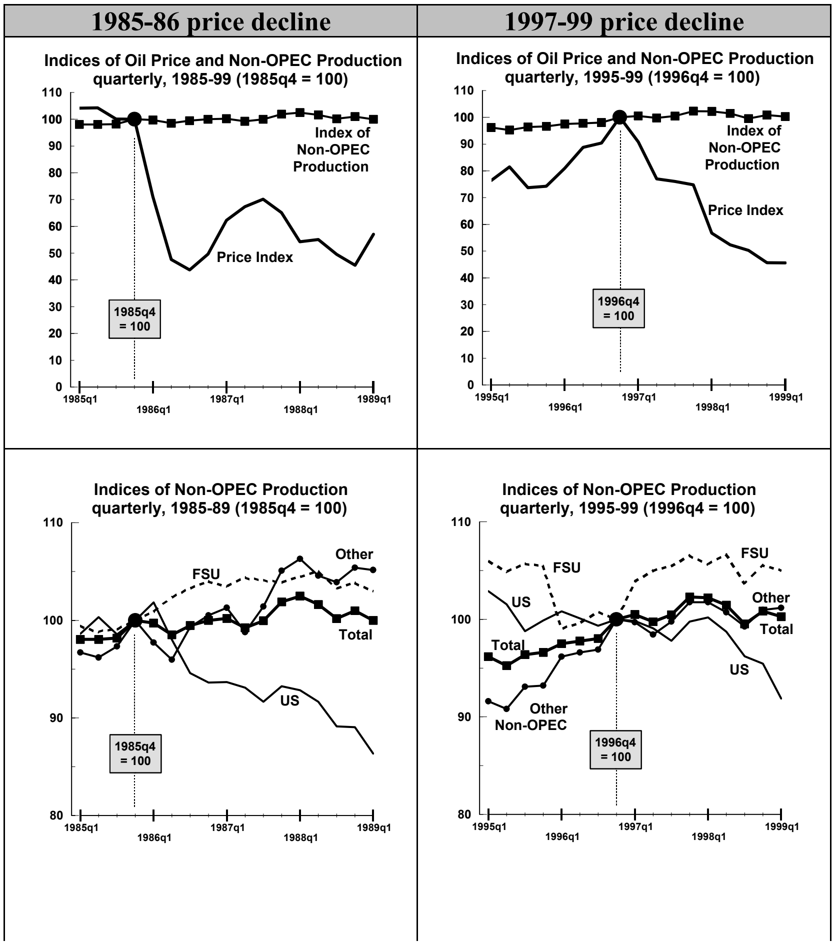
### Asymmetric Price-responsiveness of Non-OPEC supply

There are theoretical reasons why I would expect Non-OPEC supply to respond asymmetrically to price changes, with there being less response to price decreases than there had been to price increases. A standard specification for competitive oil supply, such as that in Moroney (1997) or Moroney and Berg (1999), assumes that supply is a function of oil price and oil reserves. The direct effects of oil price on supply are asymmetric, given the sunk costs of developed oil wells: keep producing as long as price is above marginal extraction cost. Price's indirect effect on supply via its effect on oil reserves is also asymmetric: oil price increases stimulate exploration and development, causing an expansion of oil reserves, but oil price decreases do not lead to a decline in oil reserves.

There is also empirical evidence to support this assertion of asymmetric price responsiveness of supply. We know from the post-1973 experience that Non-OPEC oil supply responded substantially to price increases, especially outside declining-output regions such as the US. Figure A1 depicts the Non-OPEC oil supply response to the two major price decreases, in 1985-86 and 1997-98. Consider first the episode of greatest price decline – the 1986 price collapse. The upper left graph shows indices for the Price of Crude Oil and for Total Non-OPEC Production. Each index is quarterly, covering the period from the first quarter of 1985 through the first quarter of 1989. The base quarter for each index, at which the index equals 100, is the 4$^{th}$ quarter of 1985 – just before the start of the price decline. We see that price dropped by more than half in the first two quarters of 1986. However, there was almost no apparent effect on Total Non-OPEC Production during the next three years. The lower left graph shows indices for Non-OPEC production that have been designed in a similar manner; the base quarter for each index is the 4$^{th}$ quarter of 1985, when each index equals 100. Again, we see the different paths of production in these three regions, and the flatness of the Total Non-OPEC Production index masks divergence in the three regions. In the US, the decline in production is apparent. In the Former Soviet Union (FSU), production rose slightly in 1986 then remained fairly flat. Other Non-OPEC rose slightly, especially in 1987-88.

Consider next the most recent episode of low price-responsiveness for Non-OPEC supply – the 1997-98 price decline. The upper right graph shows indices for the Price of Crude Oil and for Total Non-OPEC Production. Each index is quarterly, covering the period from the first quarter of 1995 through the first quarter of 1999. The base quarter for each index, at which the index equals 100, is the 4$^{th}$ quarter of 1996 – just before the start of the price decline. Price dropped by more than half in the 1997-98 period. However, there was almost no apparent effect on Total Non-OPEC Production during 1997 and 1998. The lower right graph shows indices for Non-OPEC production that have been designed in a similar manner; the base quarter for each index is the 4$^{th}$ quarter of 1996, when each index equals 100. Again, we see the different paths of production in these three regions. In the US, the decline in production is apparent, especially in 1998. For the FSU, the recovery of its oil production – reversing more than five years of dramatic production decline – coincided with the beginning of the price decline. Undoubtedly, the expansion of FSU production helped to force prices lower. But the lower prices did not induce greater FSU production – unless it is assumed that they pursued target-revenue behavior, and were moving down the upper segment of a backward-bending supply curve.

Figure A1. Indices of Price and Non-OPEC Production: 1985-86 and 1997-99



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