FEDERAL RESERVE BANK OF DALLAS

May 1990

Economic Review

A New Monetary Aggregate

Evan F. Koenig and Thomas B. Fomby

Reducing U.S. Oil-Import Dependence: A Tariff, Subsidy, or Gasoline Tax?

Mine K. Yücel and Carol Dahl

Economic Review

Federal Reserve Bank of Dallas

The *Economic Review* is published by the Federal Reserve Bank of Dallas. The views expressed are those of the authors and do not necessarily reflect the positions of the Federal Reserve Bank of Dallas or the Federal Reserve System.

Subscriptions are available free of charge. Please send requests for single-copy and multiple-copy subscriptions, back issues, and address changes to the Public Affairs Department, Federal Reserve Bank of Dallas, Station K, Dallas, Texas 75222, (214) 651-6289.

Contents

During the past two decades, financial innovations have proceeded at a rapid pace. These innovations have altered the liquidity of some assets relative to that of others. As a result, traditional measures of the money supply may have become less reliable as measures of household liquidity. Even sophisticated measures of the money supply, such as the Divisia monetary aggregates, do not adequately adjust for the effects of changes in the payments technology.

Koenig and Fomby propose a measure of the money supply that avoids some of the shortcomings of existing monetary aggregates. The behavior of the new measure suggests that monetary policy during the late 1970s and early 1980s was substantially less expansionary than the corresponding traditional and Divisia aggregates might lead one to believe.

Low oil prices and rising oil imports have caused growing concern about U.S. vulnerability to oil-supply shocks. Mine K. Yücel and Carol Dahl devise a measure of vulnerability and use it to compare three policies that have been proposed to reduce U.S. vulnerability to oil-supply disruptions: a 25-percent oil-import tariff, a $5-per-barrel subsidy to domestic oil producers, and an increase in the gasoline tax from 9 cents to 25 cents per gallon.

Yücel and Dahl find that the tariff would make the United States less vulnerable to disruptions. By increasing both consumer and producer prices, the tariff lowers consumption while encouraging domestic production. The increased gasoline tax could either lower or raise vulnerability. If domestic supply is not very responsive to price changes, the gasoline tax increases vulnerability. If domestic supply is responsive to price changes, the gasoline tax reduces vulnerability. The subsidy encourages increased consumption and production, leading to a faster depletion of the resource base. Hence, the subsidy would make the United States more vulnerable to oil-supply shocks.

Evan F. Koenig
Senior Economist and Policy Advisor
Federal Reserve Bank of Dallas

Thomas B. Fomby
Associate Professor of Economics
Southern Methodist University
Consultant
Federal Reserve Bank of Dallas

A New Monetary Aggregate

In 1982 the Federal Reserve Board, citing the "actual and potential effects on M1 of ongoing changes in financial technology and the greater availability of a wide variety of money-like instruments and near-monies," de-emphasized the M1 monetary aggregate as a guide to policy.[1] Similarly, in empirical research on the demand for money and on the relationship between growth in the money supply and growth in output or prices, many economists have found it helpful to introduce a shift into the published M1 series. This shift is typically placed at or near the beginning of 1981, coincident with the nationwide introduction of negotiable order of withdrawal (NOW) accounts.[2]

Unless NOW account balances are perfect substitutes for cash and demand deposits, simply adding the three assets together to obtain a measure of transaction balances (which is conventional practice) is no more appropriate than adding the number of automobiles to the number of bicycles, trains, boats, buses, and airplanes to obtain a measure of the stock of transportation equipment. A better approach is to weight the different assets by the transaction services they yield—just as in measuring the stock of transportation equipment, one would want to weight different types of equipment differently, depending on their carrying capacity and speed.

In the construction of a monetary aggregate, a variety of asset-weighting schemes have been proposed. Most have at least some intuitive appeal. The *Divisia* approach, however, stands out both for the intellectual rigor with which it has been developed and for the attention it has received.[3] The Divisia approach concentrates on measuring the *rate of growth* of the money supply rather than its level. This aggregate growth rate is taken to be an average of the growth rates of individual assets. The lower the rate of interest paid on an asset, the greater is the weight that movements in the asset receive in the Divisia measure of the rate of change of the money supply. The idea is that if people remain willing to hold an asset offering a low pecuniary rate of return, they must consider the asset especially useful as a means of payment. Accordingly, changes in holdings of assets bearing a low rate of return play a more important role in determining movements in aggregate transaction balances than do changes in holdings of high-yielding assets.

The authors wish to thank Edith A. Adams for superb research assistance and Cara S. Lown, John K. Hill, and Kenneth M. Emery for helpful comments.

[1] *Monetary Policy Report submitted to Congress on February 10, 1982, as published in the* Federal Reserve Bulletin, *March 1982. The Federal Reserve abandoned M1 targeting entirely in 1987 (Heller 1988). See Box A for definitions of M1 and related monetary aggregates.*

[2] *See, for example, Darby, Mascaro, and Marlow (1989), Rasche (1987), Stone and Thornton (1987), and Board of Governors (1982).*

[3] *William Barnett, with others, has authored a long series of papers on Divisia monetary aggregation. See, for example, Barnett and Spindt (1982) and Barnett, Offenbacher, and Spindt (1984). Alternatives to Divisia aggregation are described by Spindt (1985) and Rotemberg (1989).*

Box A

The Components and Definitions of Money

As defined by the Federal Reserve Board, M1-A was the sum of currency held by the nonbank public and demand deposits at commercial banks (other than those due to depository institutions, the U.S. government, and foreign banks and official institutions), less cash items in the process of collection and the Federal Reserve float. M1 is the sum of the items that were in M1-A plus travelers checks of nonbank issuers and other checkable deposits (OCDs). OCDs consist of negotiable order of withdrawal (NOW) and automatic transfer service (ATS) accounts at depository institutions, credit union share draft accounts, and demand deposits at thrift institutions. Beginning in January 1983, OCDs also included Super NOW accounts. Super NOW accounts paid more generous interest to depositors than did regular NOW accounts but had more stringent minimum balance requirements. After March 1986, with the elimination of interest rate ceilings on OCD accounts, the distinction between regular NOW accounts and Super NOW accounts disappeared.

The definitions used in this article are somewhat different from those used by the Federal Reserve Board. Thus, *M1A* here refers to the sum of currency held by the nonbank, nonthrift public; travelers checks of nonbank issuers; and *household* demand deposits. Business and other nonhousehold demand deposits are excluded from the analysis, on the grounds that the motives for holding such deposits are substantially different from the motives for holding household deposits (Mahoney 1988). Further, only households have the option of opening NOW accounts. Similarly, for the period during which a distinction must be made, the OCD account variable here, *N*, is a weighted sum of Super NOW and non–Super NOW OCD balances. Non–Super NOW OCD balances are given full weight, while Super NOW balances are multiplied by the ratio of the opportunity cost of holding Super NOW balances to the opportunity cost of holding non–Super NOW balances. "Household M1 balances" are the sum of *M1A* and *N*.

The Divisia index of growth in the money supply has two highly attractive features. First, construction of the index does not require detailed knowledge of the contribution various assets make to the buying and selling of goods and services: there are no functional forms to specify, and no parameters to estimate.[4] Second, the Divisia index is accurate: for any given payments technology, the index's movements fully reflect changes in transaction services.[5]

The accuracy of the Divisia index is contingent upon the assumption that the payments technology, whatever its form, is unchanging. The 1970s and 1980s, however, saw the spread of new types of transaction accounts— known collectively as other checkable deposits (OCDs)—and of innovations (like automated teller machines, money market mutual fund accounts, and money market deposit accounts) that facilitated the transfer of wealth into and out of transaction balances,

[4] *It is, however, necessary that one know, a priori, which assets are to be included in the aggregate, and that the aggregate be linearly homogeneous in its component assets (so that a simultaneous doubling of all component assets results in a doubling of the aggregate).*

[5] *Only continuous-time Divisia aggregation is fully accurate. In discrete time the Divisia index provides a third-order approximation to the true aggregate (Diewert 1976).*

making such balances more efficient. The evident changes in payments technology during the past two decades suggest that alternatives to Divisia aggregation are worth exploring.

In this article, we describe one such alternative approach—an approach that, like the Divisia index, makes use of market interest rates to weight the contributions of individual assets but which, *un*like the Divisia index, makes at least some provision for shifts in the payments technology.[6] We find that the Divisia measure of the money supply, because its construction fails to make proper allowance for the increasing availability of OCD accounts, significantly distorts the pattern of growth of transaction balances in the late 1970s and early 1980s.

Not surprisingly, in order to relax along one dimension the assumptions that underlie the Divisia approach, we are forced to make more stringent assumptions in other areas. In particular, we find it necessary to assume that the payments technology has a specific functional form. We also find it necessary to estimate one of the parameters of this technology econometrically.

In the following section, we review the rationale for Divisia aggregation. After noting the limitations of the Divisia approach, we propose an alternative aggregation procedure. Our procedure yields a monetary aggregate that, during the late 1970s and early 1980s, is much less sensitive to movements in OCD balances than is either the simple-sum or the Divisia measure of household M1 balances. Results are robust with respect to several possible changes in our assumptions. The concluding section of the article discusses the need for further research.

Divisia aggregation

Recall that the rate of change of the Divisia index of the money supply is a weighted average of the rates of change of individual assets, with greatest weight placed on the changes in assets offering the lowest rates of return. Suppose, for example, that p_a represents the interest a household loses by holding a dollar as cash or in a demand deposit account for a unit time period instead of investing the dollar in a bond or other high-yielding security. (Because cash and demand deposits pay no interest, p_a is simply equal to the interest rate on bonds.) Similarly, suppose that p_n represents the interest lost when a household keeps a dollar in an OCD account instead of in bonds. Then, if D denotes the Divisia measure of household M1 balances and $\dot{D}$ its rate of change,

$$(1)\qquad \dot{D} \equiv \left(p_a / p_d\right)M\dot{1}A + \left(p_n / p_d\right)\dot{N},$$

where $M1A$ is the sum of cash and household demand deposits; N denotes OCD account balances; and p_d, defined as $p_a(M1A/D) + p_n(N/D)$, is a measure of the average cost of holding Divisia money.

Equation 1 can be rearranged to obtain

$$(2)\qquad \dot{D} / D = s_a\left(M\dot{1}A / M1A\right) + s_n\left(\dot{N} / N\right),$$

where

$$s_a \equiv p_a M1A / \left(p_a M1A + p_n N\right)$$

and

$$s_n \equiv p_n N / \left(p_a M1A + p_n N\right).$$

According to equation 2, the percentage rate of growth of the Divisia aggregate is a weighted average of the percentage rates of growth of its individual component assets. The weights, s_a and s_n, are the shares of total "expenditures" on transaction services that are devoted to each asset. Only readily observable price and quantity information is required to calculate $\dot{D}/D$ by using equation 2.[7]

It can be shown that, as long as the payments technology is linearly homogeneous (so that a doubling of all assets doubles the flow of transaction services) and is fixed, movements in $\dot{D}/D$ will exactly match those in transaction services. (See Box B.)

[6] *The new aggregate makes allowance for shifts in technology that tend to favor one form of transaction balance over another, but it does not make allowance for changes in technology that have a uniform influence on the efficiency of all transaction balances.*

[7] *Data on price and quantity are available only at discrete time intervals. Consequently, in practice, a discrete-time approximation to equation 2 is used to construct the Divisia aggregate.*

Box B

The Accuracy of the Divisia Aggregate

A payments technology with the property that a doubling of all assets results in a doubling of financial services is said to be "homogeneous of degree one," or "linearly homogeneous." Suppose that transaction services, M, can be written as a linearly homogeneous function, $\phi(M1A,N)$, of cash, demand deposit, and OCD balances. Then the Divisia aggregate will accurately reflect movements in M. In particular, $\dot{D}/D$, calculated as in equation 2, will equal $\dot{M}/M$ at every point in time.

To see that this equality holds, note first that by direct differentiation,

$$\dot{M}/M = (M1A\phi_a/\phi)\dot{M1A}/M1A + (N\phi_n/\phi)\dot{N}/N,$$

where ϕ_a and ϕ_n are the partial derivatives of $\phi(\cdot,\cdot)$ with respect to $M1A$ and N. Because $\phi(\cdot,\cdot)$ is linearly homogeneous, however, $\phi(M1A,N)$ equals $\phi_a(M1A,N)M1A + \phi_n(M1A,N)N$ for all $M1A$ and N. (This property of linearly homogeneous functions is called Euler's Law.) Hence,

$$\dot{M}/M = \left[M1A\phi_a/(M1A\phi_a + N\phi_n)\right]\dot{M1A}/M1A + \left[N\phi_n/(M1A\phi_a + N\phi_n)\right]\dot{N}/N.$$

Suppose, finally, that households allocate their money between $M1A$ and N to minimize the cost, in forgone interest, of attaining a given level of transaction services, M. Then the marginal rate of substitution between $M1A$ and N will equal the ratio of the price of $M1A$ to the price of N: $\phi_a/\phi_n = p_a/p_n$. It follows that $M1A\phi_a/(M1A\phi_a + N\phi_n) = p_aM1A/(p_aM1A + p_nN) = s_a$ and, similarly, that $N\phi_n/(M1A\phi_a + N\phi_n) = p_nN/(p_aM1A + p_nN) = s_n$. Therefore,

$$\dot{M}/M = s_a\left(\dot{M1A}/M1A\right) + s_n\left(\dot{N}/N\right) = \dot{D}/D,$$

as claimed.

Suppose, now, that M equals $\phi(mM1A, nN)$, where m and n are parameters that vary through time as financial innovations occur. Following the steps outlined above, one can readily show that

$$\dot{M}/M = s_a\left(\dot{M1A}/M1A + \dot{m}/m\right) + s_n\left(\dot{N}/N + \dot{n}/n\right) = \dot{D}/D + s_a(\dot{m}/m) + s_n(\dot{n}/n).$$

Equation 4, in the text, is obtained in the special case in which m equals $(1-\alpha)^{\sigma/(\sigma-1)}$ and n equals $\alpha^{\sigma/(\sigma-1)}$. Thus, financial innovation is capable of destroying the accuracy of the Divisia aggregate.

Because OCD accounts pay interest while cash and demand deposits do not, p_a is greater than p_n, and the Divisia measure of the percentage growth rate of the money supply (equation 2) puts relatively greater weight on growth in cash and demand deposits than does simple-sum aggregation.[8] Because OCD balances have been rising at a faster percentage rate than cash and demand deposit balances (Chart 1), this difference in relative weights implies that the money supply growth rate, as calculated by the Divisia procedure, has generally been below the growth rate of the simple-sum measure of household M1 bal-

[8] If $M1$ denotes the sum of cash, household demand deposit, and OCD balances, then $\dot{M1}/M1 = w_a(\dot{M1A}/M1A) + w_n(\dot{N}/N)$, where w_a is defined as $M1A/(M1A + N)$ and w_n is defined as $N/(M1A + N)$ and equals $1 - w_a$. Simple algebra establishes that s_a is greater than w_a if and only if p_a is greater than p_n.

Chart 1
OCD Account Balances as a Share of Household M1 Balances

SOURCE OF PRIMARY DATA:
Board of Governors, Federal Reserve System.

Chart 2
Alternative Measures of the Rate of Growth of Household Transaction Balances

SOURCE OF PRIMARY DATA:
Board of Governors, Federal Reserve System.

ances. On the other hand, because the rapidly growing OCD balances are given at least *some* weight in its construction, the growth rate of the Divisia aggregate has exceeded that of $M1A$. In practice, the Divisia aggregate has behaved much more like household M1 than like $M1A$. (See Chart 2.)

An alternative aggregation procedure

To implement our alternative aggregation procedure, we need to assume that the payments technology has a specific functional form. We will assume, in particular, that cash, demand deposits, and OCD balances combine to yield transaction services, M, according to the formula

$$(3)\quad M = \left[\left(1-\alpha\right)M1A^{(\sigma-1)/\sigma} + \alpha N^{(\sigma-1)/\sigma}\right]^{\sigma/(\sigma-1)},$$

where α and σ are nonnegative parameters, with α less than or equal to 1. The functional form on the right-hand side of equation 3 is quite flexible and has been used in several empirical studies of the demand for money.[9] If α equals zero, OCD balances yield no transaction services, and equation 3 reduces to $M = M1A$. The larger is α, the greater are the transaction services yielded by OCD balances, at the margin, relative to corresponding services yielded by cash and by demand deposits.[10]

The parameter σ, on the other hand, measures how nearly interchangeable the two types of asset balances are. It is called the "elasticity of substitution" between $M1A$ and N. When σ equals zero, there is no possibility of substituting OCD balances for cash or demand deposit balances: the assets must be used in fixed proportions and will move together, in lockstep. In contrast, $M1A$ and N become perfect substitutes as σ approaches infinity, and equation 3 reduces to $M = [(1 - \alpha)M1A + \alpha N]$.

Only when, simultaneously, σ is infinite and α equals one-half is simple-sum aggregation of OCD balances with cash and demand deposit

[9] *See, for example, Barnett (1980, 1981) and Chetty (1969).*

[10] *Some financial innovations, such as the introduction of automated teller machines, money market mutual funds, and money market deposit accounts, will tend to increase the marginal productivity of all types of transaction balances, uniformly. The aggregation procedure we develop here is not capable of capturing the effects of such innovations. Neither are they captured, however, by the Divisia and simple-sum aggregates.*

balances justified. Only when σ or α is equal to zero is it appropriate to ignore OCD balances and use $M1A$ as a measure of transaction services. Divisia aggregation, in contrast, is valid for *any* α and σ, provided they are time-invariant.

Unfortunately, the parameter α likely did not remain constant as OCD accounts spread gradually across the nation. After all, during most of the decade of the 1970s, the only way in which a household located in, say, Texas could even use an OCD account was through the mail.[11] The cost and inconvenience associated with making OCD account deposits and withdrawals must have dropped sharply for such households in 1978—when commercial banks were allowed to offer automatic transfer service (ATS) accounts—and again in 1981—when NOW and ATS accounts became legally available at all Texas depository institutions. But lower marginal deposit and withdrawal costs are equivalent to increased marginal transaction services (Orr 1970; Milbourne 1986). So, α—the relative weight placed on OCD balances in the household liquidity function—very likely increased.

A time-varying α drives a wedge between the growth rates of M and D:

$$(4) \quad \dot{M}/M = \dot{D}/D + \left[\sigma/(1-\sigma)\right](\alpha - s_n)\,\dot{\upsilon}/\upsilon,$$

where υ is defined as $\alpha/(1-\alpha)$, so that $\dot{\upsilon}/\upsilon$ equals $[1/(1-\alpha)]\,\dot{\alpha}/\alpha$. (See Box B for a derivation.) Thus, whether increases in α raise or lower the growth rate of M relative to that of the Divisia index depends both on whether σ is greater than or less than unity and on whether the current value of α is greater than or less than s_n.

If σ is large, so that N and $M1A$ are close substitutes, then a small change in the price of one of the assets, relative to the price of the other, ought to induce a large reallocation of transaction balances away from the asset that has become relatively more expensive. Conversely, if σ is small, then even a large change in p_n relative to p_a ought to have very little impact on the allocation of transaction balances. Formally, household cost minimization implies

$$(5) \quad \ln(N/M1A) = \sigma\ln(\upsilon) - \sigma\ln(p_n/p_a).$$

Equation 5 can be differenced, then estimated econometrically, treating $\Delta\ln(\upsilon)$ as a random disturbance with nonzero mean and σ as an unknown parameter. In carrying out this estimation, we obtained a value of 0.2141 for σ, with standard error 0.1606. (Details are given in the Appendix.)

After σ is estimated, equation 5 can be turned around and solved for υ as a function of the price ratio, p_n/p_a, and quantity ratio, $N/M1A$. Equivalently, one can express υ as a function of $N/M1A$ and the ratio of expenditure shares, s_n/s_a:

$$(6) \quad \upsilon = (s_n/s_a)(N/M1A)^{(1-\sigma)/\sigma}.$$

We have already seen that the quantity ratio, $N/M1A$, was increasing during the late 1970s and early 1980s and that the estimated value of the elasticity of substitution, σ, is less than unity. Chart 3 demonstrates that s_a has been declining and, hence, that the ratio s_n/s_a has been increas-

Chart 3
Expenditures on Cash and Demand Deposit Balances as a Share of Total Expenditures on Household M1 Balances

SOURCE OF PRIMARY DATA:
Board of Governors, Federal Reserve System.

[11] *Before November 1978, interest-bearing checking accounts were available only in the New England states. The early history of interest-bearing checking accounts is discussed in Gibson (1975).*

ing. From equation 6, then, it follows that υ has necessarily been trending upward. In other words, the marginal transaction services offered by OCD balances have been rising relative to those offered by cash and demand deposit balances. Again, this finding makes sense: as OCD accounts have become available at more and more banks and thrift institutions, households have found it increasingly convenient to use OCD balances to finance their purchases.

To get a more precise notion of how υ has been behaving through time, we used equation 6 to calculate the path of υ implied by the estimated value of σ. The logarithm of this path is plotted in Chart 4. The general tendency for υ to increase through the 1970s and 1980s is apparent. Particularly rapid growth in υ occurred in 1976, when NOW accounts became available throughout New England; in late 1978, when NOW accounts became legal in New York and ATS accounts were introduced; and in early 1981, when NOW accounts became available nationwide.

From the definition of υ, α is equal to $\upsilon/(1 + \upsilon)$. Hence, equation 6 can be used to eliminate α from equation 3, yielding a formula for M that depends only on σ and readily observed price and quantity data:

$$(7) \quad M = \left[\left(1 - s_n\right) M1A^{(1-\sigma)/\sigma} + s_n N^{(1-\sigma)/\sigma}\right]^{\sigma/(1-\sigma)}.$$

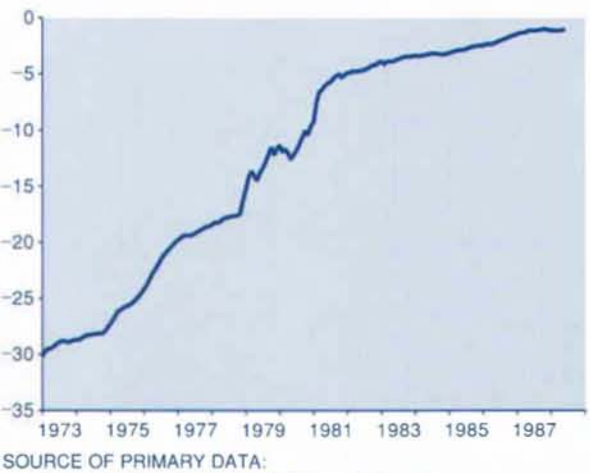
As σ approaches infinity, so that OCD balances are perfect substitutes for cash and demand deposit balances, equation 7 becomes $M = [p_a/(p_a + p_n)]M1A + [p_n/(p_a + p_n)]N$. It remains true that $M1A$ and N move together, in lockstep, when σ equals zero, so that, as before, it is appropriate to use $M1A$ as a measure of liquidity services in this case.

We will call the monetary aggregate obtained from equation 7 when σ is set equal to its estimated value the "CES aggregate," as equation 7 is derived under the assumption that there is a constant elasticity of substitution between assets.

Chart 5—like Chart 2—plots annual rates of growth of the Divisia aggregate, simple-sum household M1 balances, and $M1A$. In addition, it plots the growth rate of the CES aggregate calculated by using the value of σ obtained from estimating equation 5, 0.2141.

In Chart 5, the extent to which growth in the CES aggregate parallels that of $M1A$ during the late 1970s and early 1980s is striking. In 1981, for example, the growth rates of the CES aggregate

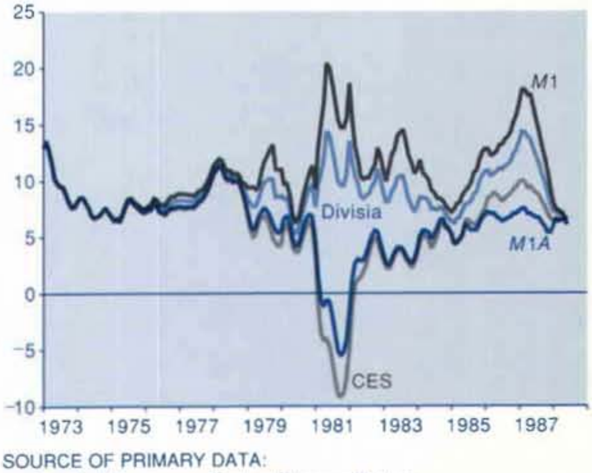
Chart 4
Effects of Shifting Technology on the Marginal Productivity of *N* Relative to the Marginal Productivity of *M1A*



SOURCE OF PRIMARY DATA:
Board of Governors, Federal Reserve System.

Chart 5
CES Aggregate and Other Measures of the Rate of Growth of Household Transaction Balances

Percent change from 12 months before



SOURCE OF PRIMARY DATA:
Board of Governors, Federal Reserve System.

and *M1A* both plummet, while those of simple-sum M1 and Divisia M1 surge. During 1983 and 1984, similarly, when the growth rates of simple-sum M1 and Divisia M1 both trend downward, growth rates of the CES aggregate and *M1A* are generally on the increase. Even after 1984, differences between the CES series and Divisia series remain quantitatively, if not always qualitatively, significant.

Sensitivity analysis

In constructing our proposed new aggregate, we assumed that the elasticity of substitution between OCD balances and cash and demand deposit balances is constant. How realistic is this assumption? If the substitutability between OCD balances and the more traditional transaction balances has, indeed, changed, the shift most likely occurred in 1981, when NOW accounts became available nationwide. Accordingly, we reestimated equation 5, allowing the pre-1981 and post-1980 values of σ to differ. No significant shift in the value of σ was detected.[12]

How important is it that σ be precisely estimated? To address this question, we used equation 7 to calculate the time path of the growth rate of the CES aggregate for three values of the elasticity of substitution: $\sigma = 0.0535$ (one standard error *below* the value of σ obtained from estimating equation 5), $\sigma = 0.2141$ (the value of σ obtained from estimating equation 5), and $\sigma = 0.3747$ (one standard error *above* the value of σ obtained from estimating equation 5).

As Chart 6 makes clear, in any given one-year period, the value of σ can indeed have a substantial impact on the estimated growth rate of the money supply. In mid-1981, for example, there is a difference of more than 6 percentage points between the annual growth rate of the money supply calculated assuming σ equals 0.0535 and the corresponding growth rate calculated assuming σ equals 0.3747. What is most striking and also most reassuring, however, is that the *qualitative* behavior of the CES aggregate is

Chart 6
Sensitivity of the CES Aggregate to Alternative Values of the Elasticity of Substitution

SOURCE OF PRIMARY DATA:
Board of Governors, Federal Reserve System.

very much the same regardless of the value of σ.

In the Divisia approach to monetary aggregation, which assumes that the payments technology is constant, every change in relative asset holdings must be attributed to a change in relative asset prices. Our estimate of equation 5 indicates, however, that most of the variation in the ratio of OCD balances to cash and demand deposit balances is unrelated to relative price changes. It is possible, though, that relative price changes have not been appropriately measured. In particular, it is possible that measuring p_n as the difference between the rate of return on bonds and the rate of return on OCD balances understates the average cost of holding OCD balances in periods during which OCD accounts were not available in all states. A more realistic approach might be to think of p_n as declining as it became legal for banks in more and more states to offer OCD accounts to their customers.

To determine how sensitive our aggregate is to possible mismeasurement of relative prices, we defined a new opportunity cost for OCD balances, p'_n, equal to a weighted average of p_n and p_a. The weight attached to p_n was set equal to the proportion of the U.S. population living in states where banks could legally offer the principal type

[12] *The difference between the pre-1981 and post-1980 elasticities of substitution was estimated to be 0.0237, with a standard error of 0.2635.*

of OCD account—the NOW account. The weight attached to p_{it} was, similarly, set equal to the proportion of the U.S. population living in states where NOW accounts were illegal. Thus, p'_{it} falls as NOW accounts become available in additional states.

A plot of the CES aggregate constructed by using p'_{it} was found to be virtually indistinguishable from a plot of the CES aggregate as constructed originally, using p_{it}. Apparently, then, the behavior of the CES aggregate is insensitive to plausible changes in the measurement of relative asset prices.

Concluding remarks

Changes over time in the ratio of the public's OCD balances to its holdings of cash and demand deposits cannot be adequately explained by changes in relative prices. This finding suggests that there have been significant shifts in the technology by which households obtain transaction services from cash, demand deposits, and OCD balances. Simple-sum and Divisia monetary aggregates, which do not make allowance for changes in the payments technology, may therefore give a misleading picture of the direction of monetary policy.

This article has outlined a new aggregation procedure—a procedure providing specifically for financial innovations that may tend to favor one asset over another. Applied to data on cash, demand deposits, and OCD balances, the procedure yields a monetary aggregate that behaves much like the household counterpart of M1-A through the late 1970s and early 1980s (as OCD accounts became more prevalent) and very differently from the household counterparts of simple-sum or Divisia M1.

The next step, a critical one, is to determine whether the CES aggregate has any closer relationship to inflation and real economic activity than do the Divisia and simple-sum aggregates. In this regard, it is encouraging that studies examining the connection between money, prices, and output during the late 1970s and early 1980s have generally found that M1-A has a closer connection to inflation and real economic activity than does M1.[13]

[13] *See, for example, Darby, Mascaro, and Marlow (1989), Roley (1985), Hafer (1984), and Wenninger (1984).*

Appendix

Econometric Specification and Estimation of Equation 5

The first-order conditions for maximizing household utility suggest the specification

$$(A.1)\quad \ln(N/M1A)_t = \sigma\ln(\upsilon_t) - \sigma\ln(p_n/p_a)_t.$$

Assuming that υ is an unobserved random variable with a positive domain, equation A.1 becomes a statistical relationship in which the elasticity of substitution (σ) is a parameter to be estimated from time series observations on ($N/M1A$) and (p_n/p_a). Estimation of σ in (A.1) can, however, be problematic. First, the stationarity of the error term, $\sigma\ln(\upsilon)$, is in question and, second, there is reason to believe that ($N/M1A$) and (p_n/p_a) are jointly endogenous.

To address the first issue, the time series $\ln(N/M1A)$ and $\ln(p_n/p_a)$ were plotted and examined for nonstationarity. The relative holdings variable, $\ln(N/M1A)$, is an increasing function of time and, thus, appears to be nonstationary in the mean. The autocorrelation function of $\ln(N/M1A)$ is slowly damping, thus reinforcing the visual pattern of nonstationarity in the mean. Differencing $\ln(N/M1A)$ to the form $\Delta\ln(N/M1A)$ stabilizes the mean and produces a quickly damping autocorrelation function. The variance profile of $\Delta\ln(N/M1A)$ is roughly of the grouped-heteroscedasticity form (Fomby, Hill, and Johnson 1984, 174–76), the groups being defined for the periods January 1973–December 1978, January 1979–December 1981, and January 1982–May 1988. There also appears to have been some intervention (outlier) behavior in the data at points of change in NOW account availability. To formalize a judgment on the nonstationarity of $\ln(N/M1A)$, unit root tests of the Phillips–Perron type (Phillips and Perron 1988) were performed. These tests explicitly allow for quite general heterogeneity in the series (the present grouped heteroscedasticity and interventions being a special case). The tests strongly supported the null hypothesis of a unit root.

In a similar manner, the relative holding costs variable $\ln(p_n/p_a)$ was investigated for possible nonstationarity. A plot of the data indicates a "slow-turning" behavior similar to that which would be exhibited by a random walk without drift. The autocorrelation function of $\ln(p_n/p_a)$ is, as expected, slowly damping. Differencing the data generates an autocorrelation function that damps rapidly. The relative holding costs variable after differencing, $\Delta\ln(p_n/p_a)$, exhibits nonstationarity in the variance of the grouped form during the same periods as the grouped heteroscedasticity of $\Delta\ln(N/M1A)$ and, also, exhibits interventions near dates of deregulatory activity. Again running unit root tests of the Phillips–Perron type, it appears that, after proper adjustment for the heterogeneity arising from grouped heteroscedasticity and deregulatory interventions, the stationary form of the relative holding costs is $\Delta\ln(p_n/p_a)$.

Even though $\ln(N/M1A)$ and $\ln(p_n/p_a)$ are both apparently first-order nonstationary, a cointegrating relationship could exist between them. Should cointegration exist, least squares estimation of equation A.1 would provide a consistent estimate of σ (Stock 1987). When the cointegration tests of Engle and Yoo (1987) were applied to our data, however, the null hypothesis of cointegration was strongly rejected.

Given the apparent first-order nonstationarity of $\ln(N/M1A)$ and $\ln(p_n/p_a)$ and the apparent absence of cointegration between these variables, we conclude that the difference form of equation A.1 is likely to lead to an amenable statistical specification with mean-stationary errors—namely, $\sigma\Delta\ln(v_t)$.

Though mean stationarity in the regression errors may have been achieved by differencing the variables $\ln(N/M1A)$ and $\ln(p_n/p_a)$, there still remains the problem of joint endogeneity between the regression variables $\Delta\ln(N/M1A)$ and $\Delta\ln(p_n/p_a)$, as well as the heterogeneity of the errors $\sigma\Delta\ln(v_t)$. With the mean of the errors $\sigma\Delta\ln(v_t)$ taken to be nonzero, the initial regression equation was

$$\text{(A.2)}\quad \Delta\ln(N/M1A)_t = \beta_1 - \beta_2\Delta\ln(p_n/p_a)_t + \theta_1 D_{t1} + \theta_2 D_{t2} + \theta_3 D_{t3} + \theta_4 D_{t4} + \theta_5 D_{t5} + \varepsilon_t.$$

In equation A.2, β_1 represents the nonzero mean of $\sigma\Delta\ln(v_t)$, β_2 is defined as σ, ε_t is defined as $\sigma\Delta\ln(v_t) - \beta_1$, and additive dummies D_{t1} through D_{t5} allow for structural change at points of NOW account deregulation. In particular,

$$D_{t1} = \begin{cases} 0 \text{ from 73:01 to 73:12} \\ 1 \text{ for 74:01 and thereafter} \end{cases}$$

$$D_{t2} = \begin{cases} 0 \text{ from 73:01 to 76:02} \\ 1 \text{ for 76:03 and thereafter} \end{cases}$$

$$D_{t3} = \begin{cases} 0 \text{ from 73:01 to 78:10} \\ 1 \text{ for 78:11 and thereafter} \end{cases}$$

$$D_{t4} = \begin{cases} 0 \text{ from 73:01 to 79:12} \\ 1 \text{ for 80:01 and thereafter} \end{cases}$$

$$D_{t5} = \begin{cases} 0 \text{ from 73:01 to 80:12} \\ 1 \text{ for 81:01 and thereafter.} \end{cases}$$

Still, ε is possibly heteroscedastic, given the observed grouped heteroscedasticity in the variables $\Delta\ln(N/M1A)$ and $\Delta\ln(p_n/p_a)$.

To obtain consistent residuals $\hat{\varepsilon}_t$ from equation A.2, spherical instrumental variable (IV) estimation was implemented (Bowden and Turkington 1984, 68–69). The instruments considered were (individually) the lagged values of $\Delta\ln(p_n/p_a)$, $\Delta\ln(N/M1A)$, and $\Delta\ln(p_a)$ in conjunction with the constant term and the additive dummies $D_{t1}, \ldots, D_{t5}$. Auxiliary regressions of the right-hand-side endogenous variable, $\Delta\ln(p_n/p_a)$, were run on up to four lags of a potential instrument (always in conjunction with the constant term and the additive dummies). Using the adjusted R^2 as a criterion for selecting lag length as well as for discriminating between potential instruments, it was found that the best set of instruments was the first and second lags of $\Delta\ln(p_n/p_a)$, together with the constant term and the additive dummies.

Because the number of suggested instruments exceeds the number of right-hand-side variables in equation A.2, we have the case of a surplus number of instruments. Of course, with the availability of a surplus number of instruments, efficient estimation is achieved through using nonspherical IV estimation, which appropriately adjusts for the heterogeneity in the errors (Bowden and Turkington 1984, 74). Nevertheless, the spherical IV estimator will produce consistent residuals, which can provide the basis for properly specifying the variance–covariance structure of the ε_t for use in subsequent nonspherical estimation.

The preliminary consistent residuals, $\hat{\varepsilon}_t = [\Delta\ln(N/M1A)_t - \hat{\beta}_1 + \hat{\beta}_2\Delta\ln(p_n/p_a)_t - \hat{\theta}_1 D_{t1} - \ldots - \hat{\theta}_5 D_{t5}]$, generated by using the spherical IV estimates, besides reflecting the grouped heteroscedasticity associated with the regression variables $\Delta\ln(N/M1A)$ and $\Delta\ln(p_n/p_a)$, also indicated substantial temporary interventions. (See Vandaele 1983 for a discussion of intervention modeling and the various possible types of interventions that frequently occur in time series data.) The interventions occurred on the dates 73:01, 74:01, 76:03, 78:11, 80:01, and 81:01, coinciding with the successive dates of deregulation of NOW accounts.

From this preliminary residual analysis, a final regression equation was chosen of the form

$$\begin{aligned}(A.3)\quad \Delta \ln(N/M1A)_t = {} & \beta_1 - \beta_2 \Delta \ln(p_n/p_a)_t \\ & + \gamma_{11} I_{t1} + \gamma_{12} I_{t-1,1} \\ & + \gamma_{13} I_{t-2,1} + \gamma_{21} I_{t2} \\ & + \gamma_{22} I_{t-1,2} + \gamma_{23} I_{t-2,2} \\ & + \gamma_{31} I_{t3} + \gamma_{32} I_{t-1,3} \\ & + \gamma_{33} I_{t-2,3} + \gamma_{41} I_{t4} \\ & + \gamma_{42} I_{t-1,4} + \gamma_{43} I_{t-2,4} \\ & + \gamma_{51} I_{t5} + \gamma_{52} I_{t-1,5} \\ & + \gamma_{53} I_{t-2,5} + \gamma_{61} I_{t6} \\ & + \gamma_{62} I_{t-1,6} + \gamma_{63} I_{t-2,6} \\ & + \theta_1 D_{t1} + \theta_2 D_{t2} \\ & + \theta_3 D_{t3} + \theta_4 D_{t4} \\ & + \theta_5 D_{t5} + \varepsilon_t .\end{aligned}$$

The only difference between (A.2) and (A.3) now is the inclusion of temporary intervention dummies $I_{t1}, \ldots, I_{t6}$ along with the first and second lags of each, the lags included to account for the inertia in the temporary interventions that is indicated by an analysis of the residuals. Evidently, the money market adjustments to NOW account deregulation were not instantaneous. The intervention dummy I_{t1} takes the value 1 for 73:01 and 0 otherwise. The dummies I_{t2}, I_{t3}, I_{t4}, I_{t5}, and I_{t6} are likewise defined according to the intervention dates 74:01, 76:03, 78:11, 80:01, and 81:01.

To verify the heteroscedasticity in its error term, equation A.3 was estimated by using the spherical IV estimator while augmenting the previous list of instruments with the intervention dummies and their first two lags as well. Again the resulting residuals were examined. As expected, the intervention dummies and their lags adjusted for the intervention behavior of the IV residuals (driving the residuals at the corresponding intervention dates to zero), and the grouped heteroscedasticity still remained. Auxiliary regressions involving the nonintervention residuals on their lagged values did not indicate significant autocorrelation. Thus, the heterogeneity in the errors (after adjusting for interventions) apparently is of the "pure" grouped-heteroscedasticity form.

In a final attempt at achieving efficient instrumental variable estimation, we chose to use a nonspherical estimator (Bowden and Turkington 1984, 69, eq. 3.3) and to model the variance–covariance structure of the regression error of (A.3) as being of the grouped-heteroscedasticity form. The instruments used were the same as those used in the previous spherical IV estimation.

Given the assumed validity of equation A.3 and the specified grouped heteroscedasticity, it follows from the Generalized Gauss–Markov Theorem (Bowden and Turkington 1984, 74) that the nonspherical IV estimator is asymptotically more efficient than the spherical IV estimator. The nonspherical IV point estimates of the parameters of equation A.3 and their respective t statistics (in parentheses) are as follows:

$$
\begin{aligned}
\Delta \ln(N/M1A)_t = {} & \underset{(1.8674)}{0.01813} - \underset{(1.3333)}{0.21409}\Delta \ln(p_n/p_a)_t \\
& + \underset{(8.2063)}{0.23157} I_{t1} + \underset{(2.0497)}{0.07660} I_{t-1,1} \\
& + \underset{(1.3184)}{0.03709} I_{t-2,1} - \underset{(-1.1108)}{0.03752} I_{t2} \\
& - \underset{(-1.2833)}{0.04370} I_{t-1,2} - \underset{(-0.2052)}{0.00606} I_{t-2,2} \\
& + \underset{(2.6385)}{0.07080} I_{t3} + \underset{(3.3366)}{0.08985} I_{t-1,3} \\
& + \underset{(1.3068)}{0.03502} I_{t-2,3} + \underset{(4.7413)}{0.18897} I_{t4} \\
& + \underset{(5.0113)}{0.18472} I_{t-1,4} + \underset{(1.8171)}{0.16253} I_{t-2,4} \\
& - \underset{(-2.1336)}{0.19232} I_{t5} - \underset{(-0.1441)}{0.01299} I_{t-1,5} \\
& - \underset{(-1.6436)}{0.14996} I_{t-2,5} + \underset{(3.9293)}{0.33657} I_{t6} \\
& + \underset{(2.3291)}{0.20069} I_{t-1,6} + \underset{(0.5099)}{0.04383} I_{t-2,6} \\
& + \underset{(2.3326)}{0.02550} D_{t1} - \underset{(-0.9354)}{0.00689} D_{t2} \\
& + \underset{(0.7080)}{0.01865} D_{t3} + \underset{(0.2860)}{0.01100} D_{t4} \\
& - \underset{(-1.8405)}{0.05288} D_{t5} + \hat{\varepsilon}_t .
\end{aligned}
$$

The basic monthly data were obtained from the Federal Reserve Board of Governors and span the period January 1973–May 1988.

References

Barnett, William A. (1980), "Economic Monetary Aggregates: An Application of Index Number and Aggregation Theory," *Journal of Econometrics* 14 (September): 11–48.

——— (1981), *Consumer Demand and Labor Supply: Goods, Monetary Assets, and Time* (Amsterdam: North-Holland Publishing Company).

Barnett, William A., Edward K. Offenbacher, and Paul A. Spindt (1984), "The New Divisia Monetary Aggregates," *Journal of Political Economy* 92 (December): 1049–85.

Barnett, William A., and Paul A. Spindt (1982), *Divisia Monetary Aggregates: Compilation, Data, and Historical Behavior*, Staff Studies, no. 116 (Washington, D.C.: Board of Governors of the Federal Reserve System).

Board of Governors of the Federal Reserve System (1982), "Monetary Policy Report to Congress," *Federal Reserve Bulletin* 68 (March): 125–34.

Bowden, Roger J., and Darrell A. Turkington (1984), *Instrumental Variables* (Cambridge: Cambridge University Press).

Chetty, V. Karuppan (1969), "On Measuring the Nearness of Near-Moneys," *American Economic Review* 59 (June): 270–81.

Darby, Michael R., Angelo R. Mascaro, and Michael L. Marlow (1989), "The Empirical Reliability of Monetary Aggregates as Indicators: 1983–1987," *Economic Inquiry* 27 (October): 555–85.

Diewert, W. E. (1976), "Exact and Superlative Index Numbers," *Journal of Econometrics* 4 (May): 115–45.

Engle, Robert F., and Byung Sam Yoo (1987), "Forecasting and Testing in Co-integrated Systems," *Journal of Econometrics* 35 (May, Annals Issue): 143–59.

Fomby, Thomas B., R. Carter Hill, and Stanley R. Johnson (1984), *Advanced Econometric Methods* (New York: Springer-Verlag).

Gibson, Katharine (1975), "The Early History and Initial Impact of NOW Accounts," Federal Reserve Bank of Boston *New England Economic Review*, January/February, 17–26.

Hafer, R. W. (1984), "The Money–GNP Link: Assessing Alternative Transaction Measures," Federal Reserve Bank of St. Louis *Review*, March, 19–27.

Heller, H. Robert (1988), "Implementing Monetary Policy," *Federal Reserve Bulletin* 74 (July): 419–29.

Mahoney, Patrick I. (1988), "The Recent Behavior of Demand Deposits," *Federal Reserve Bulletin* 74 (April): 195–208.

Milbourne, Ross (1986), "Financial Innovation and the Demand for Liquid Assets," *Journal of Money, Credit, and Banking* 18 (November): 506–11.

Orr, Daniel (1970), *Cash Management and the Demand for Money* (New York: Praeger Publishers).

Phillips, Peter C. B., and Pierre Perron (1988), "Testing for a Unit Root in Time Series Regression," *Biometrika* 75 (June): 335–46.

Rasche, Robert H. (1987), "M1—Velocity and Money-Demand Functions: Do Stable Relationships Exist?" *Carnegie–Rochester Conference Series on Public Policy* 27:9–88.

Roley, V. Vance (1985), "Money Demand Predictability," *Journal of Money, Credit, and Banking* 17 (November, pt. 2): 611–41.

Rotemberg, Julio J. (1989), "Monetary Aggregates and Their Uses: A Comment on Barnett, Hinnich and Yue's 'Monetary Policy with the Exact Theoretical Rational Expectations Monetary Aggregates'" (Paper prepared for the 14th Annual Economic Policy Conference sponsored by the Federal Reserve Bank of St. Louis, November).

Spindt, Paul A. (1985), "Money Is What Money Does: Monetary Aggregation and the Equation of Exchange," *Journal of Political Economy* 93 (February): 175–204.

Stock, James H. (1987), "Asymptotic Properties of Least Squares Estimators of Cointegrating

Vectors," *Econometrica* 55 (September): 1035–56.

Stone, Courtenay C., and Daniel L. Thornton (1987), "Solving the 1980s' Velocity Puzzle: A Progress Report," Federal Reserve Bank of St. Louis *Review*, August/September, 5–23.

Vandaele, Walter (1983), *Applied Time Series and Box–Jenkins Models* (Orlando, Fla.: Academic Press).

Wenninger, John (1984), "The M1–GNP Relationship: A Component Approach," Federal Reserve Bank of New York *Quarterly Review*, Autumn, 6–15.

Mine K. Yücel
Senior Economist
Federal Reserve Bank of Dallas

Carol Dahl
Associate Professor
Louisiana State University

Reducing U.S. Oil-Import Dependence: A Tariff, Subsidy, or Gasoline Tax?

Increased oil imports have caused growing concern in recent years. Low oil prices encouraged consumption, decreased domestic oil production, and led to higher imports. Because U.S. oil fields are relatively mature, the decline in domestic production and exploration will continue, creating a more serious oil-import problem in the future.

A disruption of oil imports or sharp increases in world oil prices could adversely affect the U.S. economy. Therefore, some observers believe the United States should reduce imports by reducing consumption and protecting the domestic oil industry. Three measures have been suggested to lower U.S. oil imports: oil-import fees, subsidies to domestic oil producers, and an increase in the gasoline tax.[1] Initially, these policies would lower current imports by either reducing consumption or increasing domestic production. The tariff would increase production and decrease consumption, the subsidy would increase both production and consumption, and the gasoline tax would reduce both production and consumption.

Because the long-term effects of these policies may differ from the short-term effects, we devised a measure of U.S. vulnerability to oil-supply shocks and traced this measure over time. We considered three specific policies discussed by policymakers—a 25-percent import tariff, a $5-per-barrel subsidy to domestic oil producers, and an increase in the gasoline tax from 9 cents to 25 cents per gallon—and determined which policy would make the United States least vulnerable to oil-supply disruptions based on our measure of vulnerability. In an earlier paper (Yücel and Dahl 1989), we evaluated the costs of these policies in the absence of a disruption. In this article, we determine the benefits of the policies in the case of a disruption.

A vulnerability measure

We measured the United States' vulnerability to oil-supply shocks by the change in economic welfare resulting from a change in imports, where *welfare* is defined as consumer plus producer surplus. The measure calculates the cost of an oil-supply shock for each year in a 50-year time horizon. Thus, the cost for each year is the change in welfare if the disruption had occurred in that particular year. We calculated the vulnerability measure under current policy and with each of the proposed policies to determine whether the new policies would reduce the costs of an oil-

We would like to thank Stephen P.A. Brown, John K. Hill, Keith R. Phillips, and Mark French for helpful comments and discussions, and David Hanna for excellent research assistance.

[1] *The U.S. Senate Finance Committee proposed an oil-import fee if oil imports were projected to exceed 50 percent of demand (Langley 1987). President George Bush, in his campaign, suggested a subsidy to oil and gas producers. Representative Daniel Rostenkowski recommended increasing the current 9-cent excise tax on gasoline by at least 15 cents per gallon (Birnbaum 1990, 1989). Federal Reserve Chairman Alan Greenspan also argued that "... a gasoline tax would do 'less harm' than other levies" (Stout 1989).*

supply disruption.[2]

The measure of vulnerability depends on the domestic price of oil, the share of imports in domestic consumption, and the elasticities of supply and demand during the disruption. A low import share would make the United States less vulnerable to an oil-supply shock, and a high import share would make the United States more vulnerable.

Vulnerability is less when demand and supply elasticities are high. A high demand elasticity means that close substitutes for oil are available to consumers if a supply disruption occurs. A high supply elasticity implies that domestic producers could respond quickly to a supply disruption by increasing domestic oil production. In both cases, a major reduction in foreign imports would be less costly for the United States. Because we calculate the effects of a temporary disruption, we use short-run elasticities in the measure.

How the policies affect vulnerability

Policies that change domestic consumption, domestic production, or the long-run supply elasticity in a given year affect vulnerability in that year. To calculate the vulnerability measure we utilized the results of our forecasting model, which calculates output paths for the Organization of Petroleum Exporting Countries (OPEC) and the United States, plus the price path of oil for the three policies and for a base case (*see the box titled "World Oil Model"*). We identified the base case as current policy, then implemented the three policies to determine how they change the price and output paths.

For each policy, we performed a sensitivity analysis using a variety of short-run demand and supply elasticities. The short-run price elasticities of demand used in our calculation of the vulnerability measure are taken to be various fractions of the long-run demand elasticity, as suggested by the economics literature.[3] These elasticities do not vary across policies.

Economists generally find the short-run supply elasticity of oil to be very low, ranging between 0 and 0.1, implying a very small output response to a price change (Hogan 1981, and Broadman and Hogan 1988). The small output response results from very high capacity utilization rates in oil production. In the case of a disruption in imports, however, the price increase is

World Oil Model

We use a dynamic optimal control model set in a partial equilibrium framework to simulate time paths for oil prices, oil production, and consumption. We model OPEC as a dominant firm facing U.S. total demand for oil, less U.S. domestic production and non-OPEC imports to the United States. Domestic producers are profit-maximizing price takers in the crude oil market. Both the United States and OPEC own reserves and maximize the present value of profits over a 50-year time horizon. We simulate the paths of the variables using an isoelastic demand function for crude oil with a price elasticity of –0.9 and an income elasticity of 0.8. The demand function was derived from domestic demand for products and normalized around 1987 demand. The cost functions for OPEC and the United States were also normalized around 1987 production costs for these regions. We assumed that U.S. income would grow 2.5 percent per year. The discount rate was 5 percent.[1]

[1] For the mathematical specification of the problem and the specific functional forms, see Yücel and Dahl (1989).

[2] *We modified the measure for the three policies to include subsidies, and tax and tariff revenues. The appendix presents this procedure.*

[3] *Nordhaus (1980) and Hogan (1981) assume that the short-run elasticity is one-tenth the long-run elasticity. Brown and Phillips (1989) find a factor of one-seventh. We conducted a sensitivity analysis using factors ranging from one-half to one-twentieth. The results reported in this article are with a factor of one-tenth.*

an unexpected short-term windfall for the producer. In such a case, one might expect domestic producers to draw from private stockpiles to take advantage of the temporary price increase. Hence, the supply elasticity could be fairly high.[4] We calculated the welfare costs of a supply shock using a variety of short-run supply elasticities ranging from 0.01 to 3. These elasticities are obtained by taking various fractions of the supply elasticities inherent in the simulations.

Base case. Under current policy, oil prices start at $20 per barrel (in 1987 dollars) and rise to $80.86 per barrel in 50 years (Chart 1). Simulated U.S. production declines fairly steeply during the 50-year time horizon to about 19 percent of its initial level, while OPEC production is fairly stable (Chart 2). Final OPEC production is only 92 percent of its initial level, resulting from OPEC's very high level of reserves coupled with relatively low and stable production costs.

The U.S. import share increases steadily throughout the 50-year time horizon to 94 percent of consumption as U.S. reserves and output dwindle and production costs soar. The welfare cost of an oil-supply disruption, based on our vulnerability measure, also increases through time due to the decline in domestic production and the increase in imports (Chart 3). Charts 4 and 5 show the price paths and domestic production paths with the base case and the three policies analyzed in this article.

Chart 1
Price Path for the Base Case

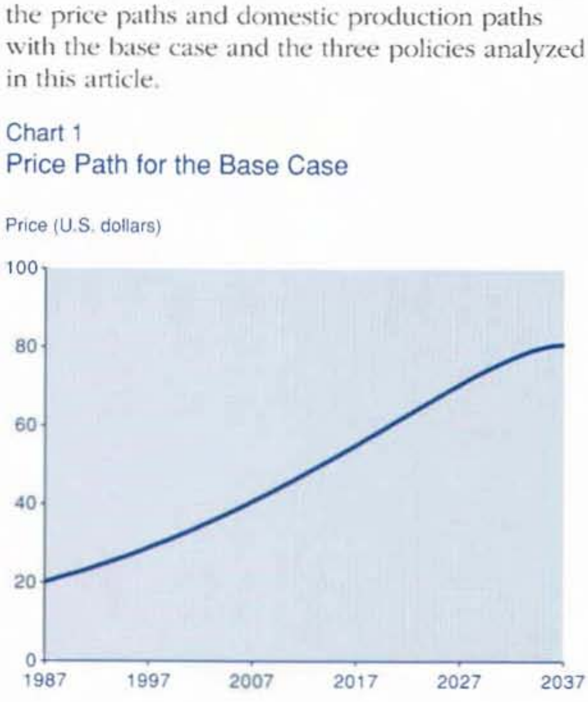
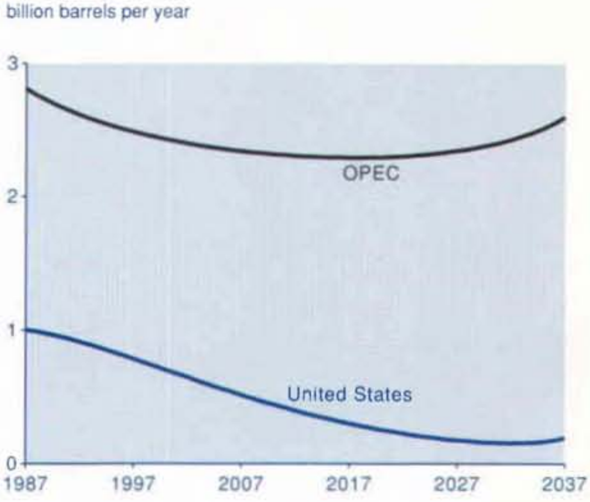


Chart 2
Output Paths for the Base Case



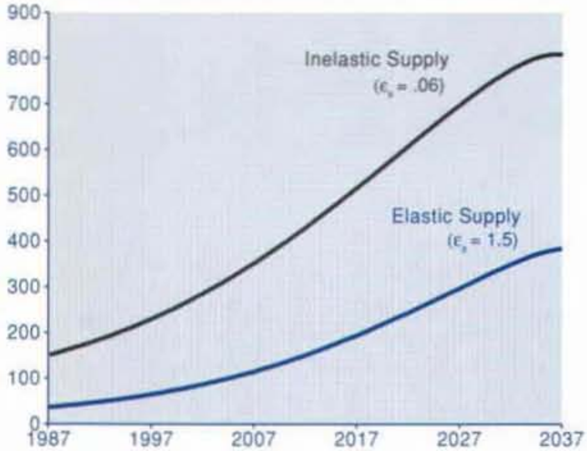
Tariff. The 25-percent tariff increases the domestic price of oil by approximately 7 percent in the early years.[5] The higher prices lead to higher U.S. production, resulting in an earlier depletion of the resource, higher production costs, and subsequently a lower production rate in the future. Overall, total discounted U.S. producer profits over the 50 years increase by 11.8 percent. OPEC, however, is worse off because it absorbs a larger share of the tariff, with total discounted profits falling by 29.2 percent.

By reducing consumption and increasing domestic production, the tariff decreases import shares. Initial import shares with the tariff are lower than with the base case for about 40 years (Chart 6). As depletion effects reduce domestic production near the end of the time horizon, the

[4] The United States also has stockpiles of oil in the Strategic Petroleum Reserve. If the federal government drew oil from the Strategic Petroleum Reserve during an oil-import disruption, the total domestic supply response would be relatively more elastic.

[5] In our model of the oil market, non-OPEC imports of oil are kept constant at their 1987 levels. If non-OPEC imports were a function of price, then a U.S. tariff would lead to somewhat higher domestic prices and a smaller decline in world oil prices.

Chart 3
Vulnerability to Oil-Supply Disruptions, Base Case Scenario



decrease in import shares becomes more modest. The tariff also lowers the total oil-import bill because it decreases the world price of oil.

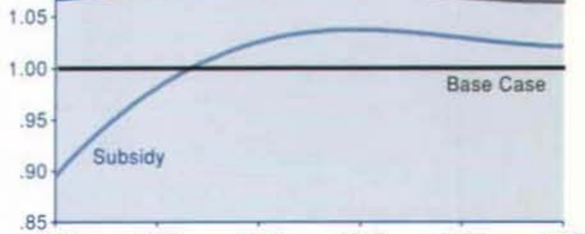
When a disruption in oil imports occurs, both consumer and producer prices increase. If domestic producers are very unresponsive to the cut in oil imports—that is, if the short-run supply is inelastic—consumers bear most of the price increase. Producers are better off than consumers after a disruption because producers receive a higher price for their relatively unchanged level of output. The higher prices and lower domestic consumption with the tariff dampen the loss in consumers' surplus due to the sudden disruption in oil supplies. The overall welfare cost of the oil-supply shock, as calculated by our vulnerability measure, is lower with the tariff than with the base case.

On the other hand, if domestic supply is very elastic and responsive to a cut in imports, domestic output expands to fill the gap created by reduced imports, and consumer prices rise little, resulting in gains in producers' surplus and small losses in consumers' surplus. Again, the welfare cost is less with the tariff than with the base case, although the difference between the two time paths is somewhat less than in the inelastic case.

The total present value of the vulnerability measure over the entire time horizon is always less with the tariff than with the base case.[6] The decrease in the vulnerability measure ranges from 11.5 percent in the case of very inelastic supply to 2.4 percent when supply is highly elastic.

Subsidy. A $5-per-barrel subsidy to domestic oil producers lowers prices in the short term but raises long-term prices for oil. The subsidy lowers the effective costs to oil producers, thus drastically increasing initial U.S. oil production. The role of the subsidy as a catalyst to domestic production decreases with time because the subsidy is constant and its discounted value decreases through time. As with the tariff, increased production leads to earlier depletion of resources, higher costs for U.S. producers, and curtailed production in later years. Although similar to the tariff case, the subsidy magnifies these effects. Surprisingly, the subsidy also increases OPEC production in the early years. Increased U.S. production in the early years reduces OPEC's market share, increases OPEC's demand elasticity, and results in higher OPEC production.[7]

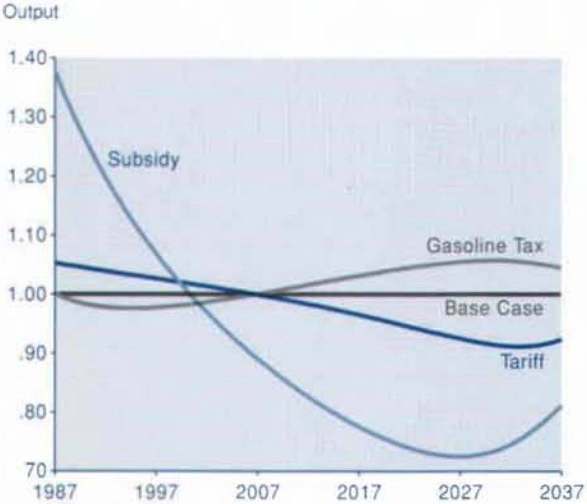
Chart 4
Effective Consumer Oil Prices, Expressed as a Ratio to the Base Case



[6] The present value calculation assumes an equal probability of an oil-supply disruption for each year in the 50-year time horizon.

[7] A downward shift that is not parallel to the initial demand function would lead to such a result for a monopolist.

Chart 5
U.S. Production,
Expressed as a Ratio to the Base Case



Although the subsidy has the lowest import share of the three policies for the first three years, import shares quickly become higher with the subsidy than with either the tariff or the gasoline tax. The subsidy encourages consumption by lowering consumer prices. The increase in domestic supply more than offsets the increase in consumption in the early years, thereby lowering imports. However, increases in both consumption and supply lead to a quicker depletion of the domestic resource base and higher imports in future years. The total cost of oil imports is also higher with the subsidy because of a higher volume of imports.

The subsidy lowers the cost of an oil-supply disruption for a short time if short-run supply is inelastic. The lower import shares in the early years help decrease the vulnerability measure. As imports increase in later years, however, oil-supply disruptions become costly. The magnitude of the loss in consumers' surplus is higher with the subsidy because of increased domestic consumption. Hence, a decrease in imports equal to the tariff case will result in higher consumer losses, and the cost of a disruption, based on our vulnerability measure, will be higher with the subsidy than with the tariff.

Domestic prices will not increase substantially if demand is very elastic, and consumer losses will be very small. With the large increase in domestic output, the subsidies paid to domestic producers will increase greatly, and the policy will always be more costly than the base case in the event of an oil-supply disruption. The total present value of the vulnerability measure is always higher than the base case with the subsidy, regardless of elasticities.

Gasoline tax. An increase in the gasoline tax from 9 cents to 25 cents per gallon drives a wedge between producer and consumer prices, with the increase in consumer prices larger than the decrease in producer prices. Because the discounted value of the producers' tax liability decreases with time, the gasoline tax in effect postpones U.S. production. Thus, domestic production declines only in the early years.

The gasoline tax lowers import shares over the entire time horizon. The tax reduces both consumption and domestic production by increasing the consumer price and decreasing the producer price. Because the tax postpones production, import shares with the gasoline tax are not the lowest in the early years. From the third year on, however, the gasoline tax has the lowest import share of all the policies, including the base case. Low import shares, however, do not necessarily imply a reduction in disruption costs. Chart 7 shows that when short-run supply is quite ine-

Chart 6
Share of Imports in Domestic Consumption,
Expressed as a Ratio to the Base Case

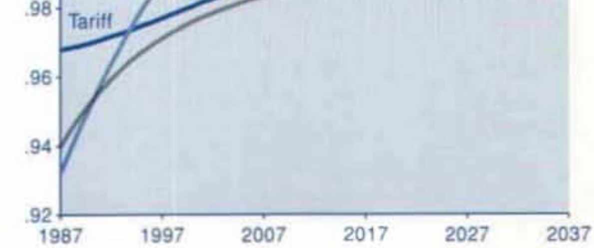


Table 1

How the Policies Change Vulnerability: Total Present Value of the Vulnerability Measure Expressed as Percentage Change From the Base Case

Short-Run Supply Elasticities*	.01	.06	.15	.60	1.5	2.0	3.0
Tariff	−11.5	−11.3	−10.9	−9.4	−7.0	−5.2	−2.4
Subsidy	3.2	4.5	6.5	12.3	17.3	19.5	22.0
Gasoline Tax	8.7	7.1	4.9	−.3	−3.6	−4.7	−5.8

* Long-run elasticities vary between policies and over time. The short-run elasticities shown above are averages for the base case. The actual elasticities vary in proportion to long-run supply elasticities for each of the three policies.

lastic (around 0.06), the gasoline tax, which lowers import shares throughout the 50-year time horizon, can be worse than the base case with respect to disruption costs.

If short-run supply is assumed to be very unresponsive to price changes (in the range of 0 to 0.6), a disruption in imports becomes costly with the gasoline tax. Low domestic production in the early years coupled with unresponsive supply makes the United States more vulnerable to supply shocks. If short-run supply is more responsive to price changes, however, the disruption in imports does not increase consumer prices very much. The lower import shares and lower consumption with the gasoline tax become the dominant factors, and vulnerability decreases with the gasoline tax.

As Table 1 shows, the total present value of vulnerability with the gasoline tax depends very much on the short-run elasticity of supply. Because domestic production is lower with the gasoline tax, the producers' response to the disruption in imports becomes a decisive factor. The gasoline tax makes the United States more vulnerable if short-run supply is very inelastic. As the short-run supply elasticity increases, however, the gasoline tax lowers disruption costs.

Summary of policies. Charts 7 and 8 show the rankings of the three policies with respect to the base case over time. The tariff clearly makes the United States less vulnerable to oil-supply disruptions whether the short-run supply response is elastic or inelastic. The subsidy could lower disruption costs in the short term if supply was very inelastic. Otherwise, the cost of a disruption is higher with the subsidy than with the base case. Similarly, the gasoline tax lowers disruption

Chart 7

Vulnerability to Oil-Supply Disruptions, Inelastic Short-Run Supply (ε_s=0.06), Expressed as a Ratio to the Base Case

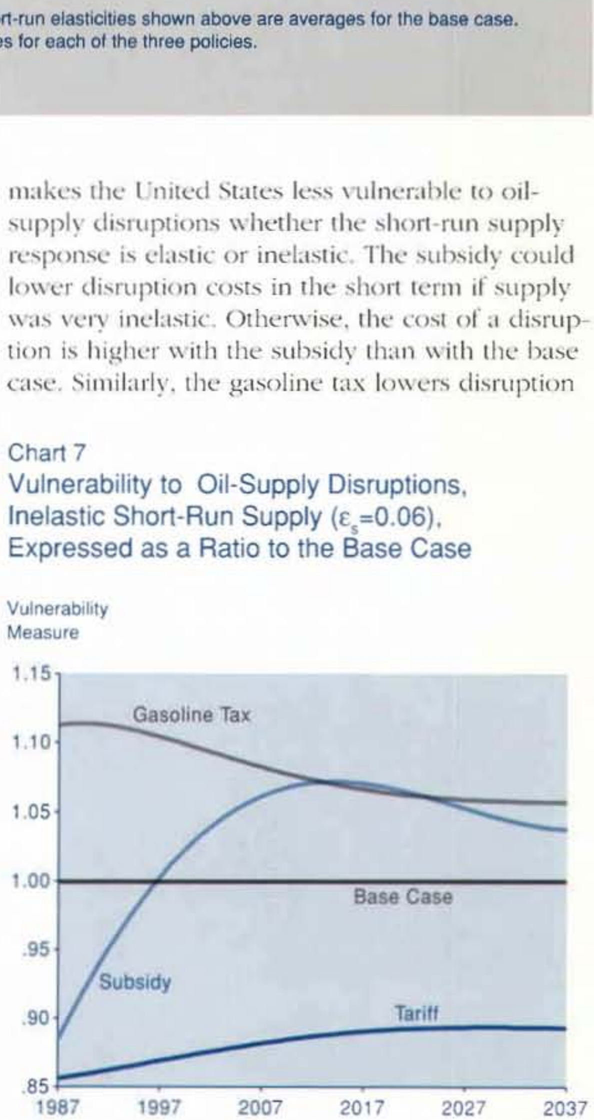
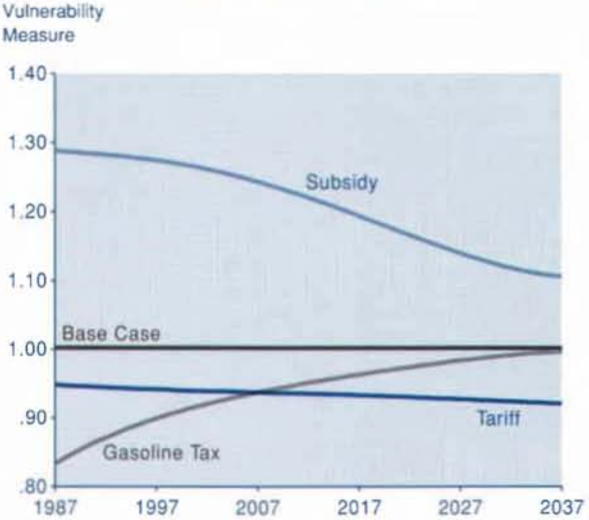


Chart 8
Vulnerability to Oil-Supply Disruptions, Elastic Short-Run Supply (ε_s=1.5), Expressed as a Ratio to the Base Case



costs for about 20 years if supply is very elastic. Yet, the gasoline tax increases disruption costs if supply is very unresponsive to price changes.

Table 1 shows the total present value of our vulnerability measure over 50 years with the different policies and different supply elasticities. The subsidy clearly makes the United States more vulnerable to oil-supply shocks. Within the range of short-run supply elasticities cited in the economics literature (0–0.1), the gasoline tax is costly as well. Our vulnerability measure indicates that the tariff is the most effective tool against supply disruptions. However, if short-run supply elasticities are higher, the cost of a disruption may be lessened by the gasoline tax. The gasoline tax could even dominate the tariff if short-run supply is very elastic.

Conclusion

Low oil prices and rising oil imports have increased policymakers' sentiments for protecting the oil and gas industry. In this article, we compared the effects of three possible measures to reduce oil imports: a 25-percent oil-import tariff, a $5-per-barrel subsidy to domestic oil producers, and an increase in the gasoline tax from 9 cents to 25 cents per gallon. One objective of these policies is to reduce U.S. vulnerability to oil-supply shocks by lowering the country's import dependence through decreased consumption, increased production, or both. If policymakers want to achieve import independence by reducing consumption, both the tariff and the gasoline tax attain that goal through increases in oil prices. The subsidy decreases import shares through increased production, but only in the short run.

Based on our measure of vulnerability, the subsidy to domestic producers will make the United States more vulnerable to oil-supply disruptions than under current policy. The tariff, on the other hand, lowers the cost of future oil-supply disruptions. By increasing both consumer and producer prices, the tariff lowers consumption while encouraging domestic production. The present value of total vulnerability is consistently lower with the tariff than with the base case.

The gasoline tax would make the United States more vulnerable to oil-supply disruptions if short-run supply is very inelastic and domestic producers could not respond to the cut in imports. However, if domestic producers could increase domestic output by fully utilizing available capacity and by drawing down private stockpiles, the gasoline tax could lower vulnerability. In the extreme case of very elastic short-run supply, the cost of a disruption with the gasoline tax could be lower than with the tariff.

Appendix

Measure of Vulnerability

In our microeconomic framework, the change in welfare caused by a supply disruption is the sum of losses or gains in consumers' and producers' surplus. At the margin, this change can be expressed as the change in imports multiplied by the infinitesimal change in price, that is,

$$(1) \qquad dW = -M\,dP = q dP - Q dP,$$

where q is domestic production, Q is domestic consumption, M is oil imports, and dP is the price change.

$$(2) \qquad M = Q(P) - q(P)$$

$$(3) \qquad dM = Q_p\,dP - q_p\,dP$$

$$(4) \qquad dP = \frac{dM}{Q_P - q_P}$$

Q_p and q_p are the partial derivatives of Q and q with respect to price. Substituting into dW and rearranging, we obtain the vulnerability measure:

$$(5) \qquad VM = \frac{dW}{dM} = \frac{M}{q_P - Q_P}.$$

VM can be expressed in terms of elasticities,

$$(6) \qquad VM = \frac{MP}{\varepsilon_s q - \varepsilon_D Q}.$$

VM is a function of imports, the price of oil, and the elasticities of supply and demand. One can similarly calculate the following modifications of VM when the different policies are in effect.

Ad Valorem Tariff:

$$(7) \qquad VM = \frac{MP^d}{(1+\tau)(\varepsilon_S q - \varepsilon_D Q)} + \tau P^w,$$

where τ is the tariff rate, P^d is the domestic price of oil, and P^w is the world price of oil.

Per-Unit Subsidy:

$$(8) \qquad VM = \frac{MP^D P^S + s\varepsilon_S P^D q}{\varepsilon_S q P^D - \varepsilon_D Q P^S},$$

where s is the per-unit subsidy, P^D is the demand price, and P^S is the supply price of oil.

Gasoline Tax:

$$(9) \qquad VM = \frac{MP^D P^S - \gamma\varepsilon_D P^S Q}{\varepsilon_S q P^D - \varepsilon_D Q P^S},$$

where γ is the gasoline tax.

References

Birnbaum, Jeffrey H. (1990), "Rostenkowski Backs Boost in Gas Tax, Would Use Defense Cuts to Trim Deficit," *Wall Street Journal*, January 3.

——— (1989), "Revenue Hunt: With Tax Rise Talk Reviving, Legislators Line Up Candidates," *Wall Street Journal*, January 5.

Broadman, Harry G. (1986), "The Social Cost of Imported Oil," *Energy Policy* 14(3): 242–52.

———, and William W. Hogan (1988), "Is an Oil Tariff Justified? An American Debate: II. The Numbers Say Yes," *Energy Journal* 9(3): 7–29.

Brown, Stephen P.A., and Keith R. Phillips (1989), "Oil Demand and Prices in the 1990s," Federal Reserve Bank of Dallas *Economic Review*, January, 1–8.

Hogan, William W. (1981), "Import Management and Oil Emergencies," in *Energy and Security*, ed. David A. Deese and Joseph S. Nye (Cambridge, Mass.: Ballinger Publishing Co.): 261–301.

Langley, Monica (1987), "Senate Rejects Plan to Keep Oil Imports From Exceeding 50% of Domestic Use," *Wall Street Journal*, July 2.

Nordhaus, W. (1980), "The Energy Crisis and Macroeconomic Policy," *Energy Journal* 1(1): 11–19.

Stout, Hilary (1989), "Fed Chairman Says Gas Tax Would Be Least Harmful Levy to Shrink Deficit," *Wall Street Journal*, February 3.

Yücel, Mine K., and Carol Dahl (1989), "A Dynamic Comparison of an Oil Tariff, a Producer Subsidy and a Gasoline Tax," Federal Reserve Bank of Dallas Research Paper no. 8912 (Dallas, August).