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IMPORT DEMAND AND SUPPLY WITH RELATIVELY FEW THEORETICAL OR EMPIRICAL PUZZLES

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ABSTRACT

This paper documents that a textbook, supply and demand, simultaneous equations model of import prices and quantities can explain many aspects of import price and quantity behavior over the past 25 years, appears to forecast better than standard trade equations, and the instruments we use appear to be valid instruments. On the negative side, although the demand equation and the two reduced form equations satisfy nominal homogeneity restrictions, the supply equation does not. One possible explanation for this is that foreign suppliers do not believe that exchange rate shocks have the same permanence as price or wage shocks. Overall, however, the findings reported in this paper show that a classical simultaneous equations model can explain the behavior of non-oil import prices and quantities fairly successfully.

U.S. Import Demand **and** Supply with Relatively Few Theoretical or Empirical Puzzles

Andrew M. Warner[1]

Given the large movements in the real value of the dollar and the stubborn persistence of the U.S. trade deficit in the 1980s, research on the market for U.S. imports has intensified in recent years. Much of the recent literature, which includes Mann (1986), Krugman and Baldwin (1987), Dornbusch (1987), Feenstra (1987), Baldwin (1988), Froot and Klemperer (1989), Moffet (1989), and Marston (1990), has emphasized import price determination, with a particular focus on the pass-through of nominal exchange rate changes to import prices. These studies have greatly increased our understanding of the variety of ways in which import prices can respond to exchange rate changes, and have done so typically by using insights grounded in the industrial organization literature. Much of the original motivation for this literature derived from evidence that import prices seemed to be insufficiently sensitive to the large depreciation of the dollar that began in 1985, suggesting that there may have been a structural break in this relationship.

Subsequent research has undercut the original empirical motivation for this literature, although the theoretical insights still retain their value. To mention just one example, Hooper and Mann (1989), found that some of the apparent break in pass-through dissolves after controlling for foreign cost variables more carefully. For example, in 1986, as continued dollar depreciation was exerting upward pressure on dollar import prices, the decline in oil prices was lowering energy costs of foreign firms at the same time, offsetting this pressure. Failure to control for the effect of falling oil prices could lead to the erroneous impression that import prices were not rising enough in response to depreciation. After controlling for foreign energy and labor costs Hooper and Mann find that only one of their equations provide evidence

[1] The author is a staff economist in the Division of International Finance. This paper represents the views of the author and should not be interpreted as reflecting the views of the Board of Governors of the Federal Reserve System or other members of its staff. Helpful comments from workshop participants at the Division of International Finance and Joe Gagnon are gratefully acknowledged, as is the tremendous research assistance of Glenn Yamagata and Peter Fishman. Errors remain my own.

for a structural break in the pass-through relationship.

On the other hand, research on import quantity determination proceeds on a separate track from this research on import prices. Although traditional import demand models have been criticized for their partial equilibrium nature, and for devoting insufficient attention to intertemporal issues, the consensus view, echoed by Krugman and Baldwin (1987), was that conventional import demand models tracked imports and exports fairly successfully:

> "The experience with volatile exchange rates since 1970 has in important respects been a vindication for such conventional modeling. With plenty of variation in the data even the simplest estimation techniques yield plausible results, and the simple equations have by and large successfully tracked the impact of the exchange rate on the trade balance."

Ironically, soon after these words were written, the forecasts of both import prices and quantities from what is perhaps the prototype trade model, the Helkie and Hooper (1988) model at the Federal Reserve Board, began to seriously under-predict both import prices and quantities, once again calling the standard models into question. Furthermore, Cushman (1990) presents evidence of a structural break in conventional models of import quantity during the mid-1980s.

The research in this paper is based on the principle of diminishing returns. Rather than emphasize what the literature has already emphasized, we examine a model where prices and quantities are simultaneously determined, on the belief that the value-added from such research can be large. On one side, the pass-through literature either ignores or de-emphasizes simultaneous interaction between prices and quantities. And this aspect of the models is usually not confronted or defended with evidence. On the other side, import demand models often assume a recursive structure, where prices are first determined and then import demand is estimated conditional on prices. There are several studies which estimate import demand with instrumental variables, but none also consider price determination. The result of this separation is that the literature does not have a full blown study examining whether the same model can explain both import prices and quantities.

The evidence reported here suggests that this separation between models of import prices and models of import quantities is not an innocuous gap in the literature but rather may be partly responsible for many of the empirical problems that seem to crop up periodically with the standard trade model. We propose an integrative model that determines prices and quantities simultaneously and also incorporates the main insights of the recent literature in this area. The econometric estimates of this model satisfy virtually all of the textbook properties that a well defined simultaneous equation model should satisfy, and at the same time, the reduced form equations from this model do not exhibit any structural break in the pass through relationship, and they appear to resolve the recent forecasting problems of the Helkie-Hooper model. These points are made with a structural model which has a straightforward interpretation as a classical supply and demand model but which is not limited to that perspective.[2]

Although the model benefits from previous results in the literature in many respects, it is a generalization on the standard models in two key ways. First we explicitly model an import supply equation and estimate it along with more standard import demand equations. This permits a test of the common practice of implicitly assuming that the import supply function is horizontal so that prices and quantities can be modeled recursively. The data reject this assumption. This result means that exogenous variables entering the import supply equation belong in the reduced form forecasting equation explaining equilibrium import quantities, and similarly, that exogenous variables entering demand also belong in the price forecasting equation. We then show that forecast of both prices and quantities from this framework outperform forecasting equations from the standard model and are capable of explaining the observed

[2] The absence of a supply and demand model in the empirical literature on imports probably reflects difficulty in finding instruments. Haynes and Stone (1983) tried to estimate import supply but were not successful essentially because they used the wrong variables. When asked by the International Monetary Fund to assess the effects of exchange rate devaluation on trade flows, Orcutt (1950) was one of the first to reason within a simultaneous equations framework, and address simultaneity bias, but unfortunately was pessimistic that separate estimates of supply and demand could ever be obtained. The evidence in this paper shows that Orcutt need not have been so pessimistic.

movements in both prices and quantities in the past four years that the standard equations are unable to explain. The standard forecasting equations can be seen as special cases of the supply and demand model where the supply equation is deterministic and has a slope of 0.

Second, the model also allows imports to respond differently to different kinds of spending: private consumption, public consumption, and investment spending. This allows us to statistically exclude government spending as a determinant of imports and to show that imports respond differently to consumption and investment spending. This is also partly responsible for improving the models ability to track recent movements in import prices and quantities.

The paper uses both classical and modern econometric techniques, partly to show that the model is amenable to both perspectives. The structural equations are estimated with classical instrumental variables estimation where instruments for demand are taken from supply and vice versa. We show that the structural estimates pass many of the tests one would expect of such equations if the assumptions about exogeneity are true.

The reduced form forecasting equations are first estimated with a specification that makes them comparable with the Helkie-Hooper model and then in a way which uses more recent econometric techniques that emphasize dynamics and cointegration. The evidence from the error correction framework suggests that both prices and quantities are cointegrated with the vector of exogenous variables in demand and supply.

I. Analytical Framework.

This section outlines an analytical framework to describe the reasoning behind the model we estimate. First, we will assume that there is a representative U.S. consumer or firm[3] that derives utility from an aggregate import good and an aggregate home good. These two goods are assumed to be imperfect substitutes in demand and therefore have distinct prices, denoted P_m and P respectively. We do not model the consumption-saving decision: instead, we take total spending, denoted by Z, as given and focus on the problem of dividing that spending between home goods and imported goods.[4]

$$Max \quad U = (C_m, C) \tag{1}$$

$$s.t. \quad P_m C_m + PC = Z \tag{2}$$

This problem produces an import demand function that depends on the two prices and total expenditure.

$$C_m = g(P_m, P, Z) \tag{3}$$

Equation (3) captures the essential features of the classic import demand equation. In contrast to the large number of studies on import demand, relatively little attention has been devoted to the supply

[3] No important distinction is made between the kind of buyer (consumers or firms) or the kind of import good (consumer durable, producer durable, or non-durable). We go part of the way in addressing the first issue in the empirical section by using consumption and investment spending as separate spending variables in the import demand function. Also, Burda and Gerlach (1989) have recently focused on the durables / non-durables distinction.

[4] Technically, weak separability and linear homogeneity of the utility function as employed in Helpman and Krugman (1985, chapter 6), and many others, is sufficient to ensure that the consumer's maximization problem can be simplified into a two stage budgeting problem, where in one of the stages, as above, the consumer chooses spending on particular commodities conditional on total spending.

side of the U.S. import market.[5] Some studies implicitly assume that the supply function is horizontal by modeling import prices in a way that does not depend on import quantities. Hooper and Mann (1989) assume that foreign exporters to the U.S. market set export prices in their own currency, P_x, to equal a markup, λ, over their own-currency marginal costs, C_q. Dollar import prices, P_m, are then obtained by dividing through by the exchange rate, E, defined as foreign currency per dollar.

$$P_m = \frac{P_x}{E} = \frac{\lambda C_q}{E} \tag{4}$$

The markup in turn is assumed to depend on the ratio of dollar prices of other U.S. goods to foreign marginal costs expressed in dollars, $(EP/C_q)^\alpha$, and foreign capacity utilization, CU^β, yielding the following import price equation.

$$P_m = \left(\frac{C_q}{E}\right)^{1-\alpha} P^\alpha CU^\beta \tag{5}$$

In this framework the import market is assumed to have a recursive structure where import prices are first determined according to an equation such as (5), and then prices are treated as independent variables on the right of import demand equations which determine import quantities. This is also the basic approach in Ahluwalia and Hernandez-Cata (1975), and Helkie and Hooper (1988).

An alternative is to consider a profit maximizing foreign firm pricing in an environment of

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[5] Haynes and Stone (1983) appears to be the only attempt to estimate supply equations for total imports to the U.S., with limited success. Some researchers have estimated export supply functions for specific countries or regions which export to the U.S., such as Goldstein and Khan (1978), for Europe, and Ueda (1983), for Japan. In addition, other authors, such as Grossman (1982), have the supply side in mind in choosing instruments to identify import demand, but do not estimate separate supply equations. Gagnon (1989) models the resale decision of U.S. importers, rather than the supply decision of foreign firms.

monopolistic competition as in Helpman and Krugman (1985), or Gagnon and Knetter (1990), where dollar import prices are set to equate marginal revenue with marginal costs according to the familiar formula (note that P_m is in dollars and C_q is in foreign currency so that either one or the other has to be converted with an exchange rate).

$$P_m = \left[1+\frac{1}{\eta}\right]^{-1}\frac{C_q}{E} \tag{6}$$

In this setup, the import market will also have a recursive structure if both the elasticity of demand, η, and marginal costs, C_q, are invariant to import quantity.[6]

Although a number of studies are based on versions of equation (5) or (6) which do not allow import quantities to enter on the right, there is no strong theoretical reason that prevents such a relationship. To the contrary, there are good theoretical reasons to think that prices and quantities will interact simultaneously. In the monopolistic competition pricing equation (6) the elasticity of demand can easily depend on the size of the market.[7] Furthermore marginal costs can easily depend on quantities to the extent that certain factors are subject to diminishing returns.

In this paper we will allow import quantities to affect marginal costs and let the data determine whether this relationship is important. The marginal cost function for the representative foreign firm is

[6] For formal justifications, a model with Spence-Dixit-Stiglitz preferences yields a constant η, and with Lancaster preferences η is a function of all the arguments in the demand function except total expenditure, because preferences are assumed to be homothetic.

[7] For a concrete example, with a monopolistic competition model as in Helpman (1981), the elasticity of demand increases with the number of firms or the available number of varieties. A larger import market can accommodate more varieties and thus increase the elasticity of demand.

assumed to depend on output, foreign unit labor costs and the price of oil.[8]

$$C = C(q,w,P_{oil}) \tag{7}$$

With this marginal cost function, it is straightforward to derive an upward sloping industry supply function in a competitive model. Competitive foreign firms, taking dollar import prices as given, will choose quantity to equate import prices in their currency with domestic marginal costs. Horizontal summation of the marginal cost curves generates an upward sloping short run import supply function in P_m - Q_m space that also depends on the exchange rate and the other variables in the cost function.

$$P_m = g(Q_m,E,w,P_{oil}) \tag{8}$$

In the empirical section, we will estimate log linear versions of equation (8) and treat it as an industry supply function in a competitive market. However, this is done for expository convenience. The structural relationship given by (8) could be derived from a variety of other models, including of course (5) or (6). Almost any model would have a role for wages, intermediate goods prices, and exchange rates in supply decisions.[9]

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[8] Labor costs typically account for a large fraction of total costs and have been used by some other studies as instruments to identify import demand, (see Grossman, 1982). In addition, Bruno and Sachs (1985), among many others, have emphasized the importance of oil as a key intermediate input in many of the countries which supply U.S. imports, and of course oil prices have fluctuated substantially in the past 25 years. Ueda (1983) models Japanese export supply as depending partly on oil prices and Hooper and Mann (1989) include energy prices in their import price equation.

[9] At least as far as the reduced form relationships are concerned, there is a substantial observational equivalence between prefect competition and imperfect competition models. For example, a positive shock to wages would increase the equilibrium price and reduce the equilibrium quantity in several models.

2. Econometric model and data.

We adopt the simplest possible log-linear specification for the system of equations which we will treat as a supply and demand system.[10] All variables are in logs although not written explicitly that way.

Supply Equation:

$$Q_m^s = \alpha_0 + \alpha_1 P_m + \alpha_2 E - \alpha_3 W - \alpha_4 P_{oil} + \alpha_5 D + \epsilon_s \tag{9}$$

Q_m Real non-oil merchandise imports, in 1987 dollars.

P_m Fixed weighted price index for non-oil merchandise imports, in dollars (1987 weights).

E Nominal exchange rate index for the G-10 countries: foreign currency per dollar, non-oil import weights.

W Unit labor cost index of G-10 countries, in local currency units, non-oil import weights.

P_{oil} Oil price index in foreign currency units (dollar index times E variable above).

D Dock Strike variable.[11]

Demand Equation:

$$Q_m^d = \beta_0 - \beta_1 P_m + \beta_2 P + \beta_3 C + \beta_4 I + \beta_5 G + \epsilon_d \tag{10}$$

P The U.S. CPI (1967=100).

C Real private consumption spending, billion 1987 dollars.

I Real private investment spending, billion 1987 dollars.

C Real government spending, billion 1987 dollars.

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[10] The evidence in Khan and Ross (1977) supports a log-linear rather than linear specification for aggregate U.S. import demand, however Marquez (1992) has recently challenged the constant elasticity implications of such a framework.

[11] This dock strike adjustment factor relies on Isard (1975), who calculated it by comparing predicted longshore manhours (without strikes) to actual longshore manhours. There were three such strikes in the late 1960s and early 1970s. In a log specification, this variable should have a coefficient of one.

3. Instrumental Variable Estimates of Supply and Demand.

Tables 1 and 2 present instrumental variables estimates of the demand and supply equations using quarterly data between 1967:1 and 1991:3. A number of theories would suggest several homogeneity restrictions across the estimated coefficients of these equations. We test such homogeneity restrictions but do not impose them a-priori on the estimation.

Because the expenditure variables (U.S. consumption, investment and government spending) and the U.S. CPI variable enter demand but not supply, these IV estimates use exogenous variation in these variables to identify the slope of the supply equation. Similarly, the estimates use exogenous variation in three variables which enter supply but not demand, namely, the exchange rate, the foreign unit labor cost index, and the oil price index, to identify the slope of the demand curve. Because these identifying assumptions are at the heart of the economics and the estimation strategy, tests of their validity will be examined below.

The initial estimates of the structural model in tables 1 and 2 are straightforward IV estimates with all variables entered contemporaneously. The tables report conventional standard errors in the second column which are probably too low given that the equations exhibit positive serial correlation, and, to err in the other direction, the third column reports serial correlation and heteroscedasticity (HSC) robust standard errors which are computed in the manner recommended by Wooldridge (1989). The econometric strategy here is to be deliberately agnostic about the form of serial correlation and/or heteroscedasticity and to see how much difference this makes to the estimated standard errors. Alternative estimates of these equations with explicit AR1 error structures and additional dynamics will also be considered below.

The estimates are generally encouraging. With the exception of the insignificant coefficient on the government spending variable in the demand equation, all coefficients have the anticipated sign and most are significant. Concentrating first on the estimated slopes of the two curves, note that the estimated slope of the import demand function in table 1 is -0.862, and is highly significant when evaluated with either standard error (conventional standard error = 0.084, robust standard error = 0.155). For comparison, a similar import price coefficient in Helkie and Hooper is -1.238. Obviously, since real imports are on the left of these regressions, this is an estimate of the slope in q-p space. A consistent estimate of the demand slope in p-q space would be given by the inverse, or 1/(-.862)=-1.160.

The estimated slope of the import supply function in table 2 is 3.970, which translates into a fairly flat slope (in p-q space) of 0.252. Unlike the demand slope, in this case there is a substantial difference between the robust standard error (1.769) and the conventional standard error (0.529), but the estimated coefficient is still statistically significant (five percent) even with the higher standard error. To provide an intuitive picture of these estimates, figure 1 draws the estimated equations in p-q space. As can be seen, the estimated supply equation is fairly flat and the estimated demand equation has a slope which is slightly steeper than negative one. This figure will be useful in interpreting the magnitudes of the reduced form effects presented latter in the paper.

Turning to the other regressors in the demand equation, the consumption and investment expenditure variables both have positive and highly significant coefficients no matter what standard errors are used. The estimates indicate a higher sensitivity of non-oil imports to consumption demand rather than investment demand over the past 25 years. Holding investment spending constant a one percent rise in consumption is estimated to raise real import demand by 1.569 percent; while a similar ceterus paribus rise in real investment demand is estimated to raise real import demand by a smaller 0.568 percent. Note that the estimated government expenditure effect is negative and insignificant with either standard error. This can be explained by political pressure on government agencies to buy locally-produced products rather than imports. For example, most local police departments use domestic autos for police cars, and large defence contracts typically are awarded to U.S. firms. The final point to note in table 1 is that the coefficient on the price of other goods and services (measured by the CPI) is positive and highly significant, suggesting that the aggregate good as represented by the CPI is a substitute in demand for imports. Note that although the estimated demand equation does not impose nominal homogeneity a-priori, the estimated coefficients on both price variables are virtually equal and of opposite signs: a proportional change in all nominal prices leaves real demand unchanged.[12]

On the supply side in table 2, the exchange rate coefficient indicates that an appreciation of the dollar of one percent shifts quantity supplied by 1.945 percent at any given dollar price of imports. The robust standard error is much larger than the conventional standard error in this case, and this affects the statistical significance of the coefficient. Because of this ambiguity, we tried additional econometric specifications and found no additional evidence that the exchange rate effect is insignificant. Three stage least squares yielded an estimated standard error of only 0.178; estimation with AR1 errors yielded a standard error of 0.708.

The two cost variables in the supply function, unit labor costs and the price of oil, are both estimated to reduce quantity supplied at any given dollar import price. The magnitude of the unit labor cost effect is higher but more imprecisely estimated than the oil price effect. Both coefficients are significant using the conventional standard errors; but the unit labor cost elasticity is not significant with the robust standard error. In this case 3SLS estimation produced a standard error of 0.480, and AR1 estimation yielded a fairly high standard error of 1.522. Therefore, the evidence at this stage is mixed concerning the statistical significance of the foreign unit labor cost effect.

There are at least two homogeneity restrictions that one may wish the supply equations to satisfy. The first is that quantity supplied should be invariant to inflation in all foreign prices which is offset exactly by dollar appreciation. Recalling that the oil price variable is a dollar oil price times the exchange rate, this restriction, in terms of the notation in equation (9), is $\alpha_2 - \alpha_3 - \alpha_4 = 0$. When the supply

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[12] Grossman (1982) argues that the failure to find price homogeneity in import demand suggests mis-specification, and therefore uses these tests to validate import demand equations.

equation is estimated with lag variables, as in table 5, the data do not reject this restriction (significance level = 0.80); however the data do reject this restriction in table 2 (significance level = 0.03). The second homogeneity restriction is that if the dollar appreciates by one percent, foreign suppliers should be willing to supply the same quantity as before at a one percent lower dollar import price. Alternatively stated, the supply curve should shift down vertically by one percent in response to a one percent nominal appreciation. This restriction, namely that $-\alpha_1 + \alpha_2 = 0$, is strongly rejected by the data in both table 2 and 5.

Given the importance of the identifying assumptions for the estimation, we checked the identifying assumptions and the quality of the instruments in two ways. First, since the model is over-identified, there are several possible instrumental variables estimators, corresponding to different combinations of the instruments. If all the instruments are valid, the 2SLS estimator (using all of them) is most efficient, yet the others are still consistent. If the model is true, we should expect to find that the various IV estimates are close to each other (allowing for the standard errors) and that the standard errors increase as fewer instruments are used.

To check this, a number of alternative IV estimates are presented in table 3. For both supply and demand, the table presents seven different IV estimates from the group of three instruments, with the 2SLS estimate at the top. Given the evidence for serial correlation in tables 1 and 2, the estimated equations in table 3 allow for AR1 errors. As can be seen from the top panel, the IV estimates of the demand slope (in q-p space) appear fairly close, usually ranging between -0.82 and -0.94. The outlier is the estimate of -0.58 obtained when the oil price is the only instrument, but the standard error is fairly high in this case (0.43), reflecting the inefficiency of using a single instrument. Overall, the estimates do not seem too far apart after taking the standard errors into account. On the supply side in the bottom panel of table 3, the estimates seem more sensitive to the instrument list, but the standard errors are also higher. Again, given the standard errors, there does not seem to be strong evidence against the view that the instruments produce similar estimates.

A second check on whether the instruments are valid is to examine whether the instruments are statistically unrelated to the residuals in the equations from which they are excluded. The last two column of table 3 presents tests of these over-identifying restrictions (of course, the test is possible only in the four cases where the model is over-identified). These tests follow Hansen (1982). Under the null that the errors are unrelated to the instruments, and with no heteroscedasticity or serial correlation, the test statistic is the sample size times the R^2 of a regression of the residuals on the instruments. This statistic follows a Chi-square distribution with degrees of freedom equal to the number of over-identifying restrictions. In table 3, where we are estimating one parameter with three or fewer instruments, we have either 1 or 2 over-identifying restrictions (the 5 percent critical values for the Chi-square are 3.841 for one degree of freedom and 5.991 for two). Table 3 shows that one can easily accept the null that the instruments are unrelated to the errors in the demand equation since the test statistic is uniformly far below this critical value (the significance levels on the far right column of table 3 confirm this). The evidence is a little more mixed on the supply side. The 2SLS estimate at the top, yields a chi-square statistic of 5.77, which is almost significant at the five percent level. Therefore, it may be prudent to prefer one of the other IV estimates where the over-identification test fails to reject, such as the 6.764 estimate when Ln(I) and Ln(P) are used as instruments. With this estimate, the supply slope would be even flatter than that depicted in figure 1.

In an earlier attempt to estimate an import supply function for the U.S., Hayes and Stone (1983) found sharply different results depending on whether prices or quantities were specified as the dependent variable.[13] With import quantity on the left, they obtained a counter-intuitive own-price elasticity of -

[13] Their specification differs in several important respects from the specification in this paper. They use total imports rather than non-oil, they use unit value import prices, and their other regressors are foreign wholesale prices, foreign trend income and the deviation of foreign income from trend income.

0.59, and some other incorrectly signed coefficients. However, with import prices on the left, they obtained a positive elasticity, 0.10, as expected. They state that it is unclear a-priori whether quantities or prices should be the dependent variable, and use their results as evidence that the latter specification is preferable. A more reasonable perspective may be that if the empirical model is correct, this issue should not make much difference for the estimates, and may be evidence of mis-specification if it does.

To check this issue, we can first invert the supply equation we estimated with q on the left, estimate the same equation, and then compare results. First recall that the estimated equation in table 5 is essentially the following: $\ln(M) = c + 4.185\ln(pm) + 2.219\ln(E) - 1.899\ln(ULC) - 0.598\ln(P_{oil})$. Inverting this equation algebraically, we obtain $\ln(pm) = 1/c + 0.24\ln(M) - 0.53\ln(E) + 0.45\ln(ULC) + 0.14\ln(P_{oil})$. Estimating this inverted equation using the same lags, error structure and instruments as the non-inverted equation, we obtain $\ln(pm) = 1/c + 0.14\ln(M) - 0.45\ln(E) + 0.59\ln(ULC) + 0.12\ln(P_{oil})$. Because the coefficients from the algebraically inverted equation fall well within two standard errors of the coefficients in the estimated equation, it seems that the supply equation here is invertible.

Finally. given the absence of import supply estimates in the literature, it may be of interest to understand what aspects of the statistical procedure in this paper are responsible for the positive coefficient on the import price variable in the supply equation.[14] Part of the answer is the instrumental variables procedure. The estimated import price coefficient falls to 2.22 from about 4.0 when the model is estimated with OLS without any instruments, which is the pattern we would expect since OLS estimates are biased towards zero in the presence of simultaneity. The other part of the answer is that we control for exchange rates and oil prices in the supply equation, unlike previous studies. For example, dropping the exchange rate variable by itself reduced the import price coefficient from 2.22 to -0.54, and dropping

[14] In this data the simple correlation between relative import prices and quantities is negative. A simple regression of the log of real imports on the log of the import price index over the CPI delivers an estimated coefficient of -2.19 with an R^2 of 0.30 (and hence a simple correlation coefficient of -0.55).

the oil price variable by itself reduced the coefficient from 2.22 to -0.94. In contrast, the import price coefficient was insensitive to the presence of either the unit labor cost coefficient or the dock strike dummy. Therefore, both the instrumenting procedure and controlling for exchange rates and oil prices seem to be important in estimating import supply.[15]

[15] We also checked the performance of foreign capital stock measures in the import supply equation and the unrestricted reduced form equations. We used the Federal Reserve's import-weighted index of the capital stock in the rest of the world (the capital stock in firms that actually export to the U.S. would have been preferable but is hard to measure), as a proxy for the ability of foreign firms to supply the U.S. market. This variable should shift supply to the right.

Under IV estimation of the supply curve with conventional standard errors, the foreign capital stock variable has an elasticity of about +1.6 (for a given p_m, it increases quantity supplied, as expected), and is significant. None of the other estimated coefficients changed signs; typically, they are lower in absolute value, but only slightly so in many cases. The most important change is that the estimated import price coefficient falls from around 4 to around 2, which translates into a steeper import supply function in p-q space. Under some specifications the homogeneity restrictions are no longer rejected. Furthermore, estimation with the restrictions imposed tends move the estimated coefficients closer to zero. In unrestricted estimation of the reduced form equations, the capital stock variable has the wrong sign in the price equation and its presence causes a negative coefficient on the consumption variable in the quantity equation.

4. Reduced form equations, forecasting performance and pass through.

To examine whether the model here resolves the recent forecasting problems of the standard models, this section compares forecasts from the reduced form with the Federal Reserve's trade equations. The Federal Reserve's model, based on Hooper (1976), Isard (1975), Helkie and Hooper (1988), and Meade (1990) determines import prices first with a markup equation similar to equation (5), where import prices are regressed on lags of a world commodity price index, foreign consumer prices as a proxy for foreign marginal costs, and lags of the import-weighted dollar exchange rate index. Import quantity in turn is regressed on the same import price, U.S. GNP, the dock strike variable, foreign capacity utilization, and the ratio of the U.S. capital stock to an index of the aggregate capital stock of the rest of the world. Recent estimates of the model are in Helkie and Hooper (1988).

To improve comparability with the Federal Reserve model, the reduced form model was estimated with the non-oil, *non-computer* import price and quantity data currently in use at the Federal Reserve and described in Meade (1990). We also mimicked the lag specification of the Federal Reserve model by using seven lags of the exchange rate variable in both the price and the quantity equations, and by using three lags on the CPI, unit labor cost, and oil price variables in the price equation. After having discovered that it has little effect on the results, for simplicity we do not use the PDL structure on the lags nor the AR1 correction used by the Federal Reserve model. The estimates of the unrestricted reduced form are displayed in tables 6 and 7. Once again, the government spending variable was found to have the wrong sign and was insignificant and therefore omitted. All of the other variables have the anticipated signs. In addition, although two of the demand variables, consumption and investment, are individually insignificant, they are jointly significant. The F-statistic testing whether these two variables can be excluded from the price reduced form is $F(2,54)=8.5$, which has a significance level of 0.0006. Similarly, in the import quantity reduced form, there are two supply variables which are not conventionally included in import equations, namely unit labor costs and oil prices. Exclusion tests on these variables also indicate that they are jointly significant, since the F-statistic is 11.37 with a significance level of 0.00006. This evidence suggests that the demand variables do enter the price reduced form and the supply variables enter the quantity reduced form.

It is also worth recalling from the instrumental variables estimates that the supply slope in this model is fairly flat. This explains why the demand variables in the reduced forms have small estimated effects on price and relatively large estimated effects on quantity.

The out-of-sample forecasts from the two models are presented in figures 2 and 3. Both models were estimated by OLS on data between 1967:1 and 1986:4, and used to forecasts import prices and quantities for the period 1987:1-1991:3. As can be seen from the figures, the forecasts from the reduced form model seem to track actual import prices and quantities better than the Federal Reserve model throughout the forecast period, although there are some sub-periods, such as 1990-1991 for prices and 1988-1989 for quantities, where the reduced form forecasts are somewhat above the actual data. On balance however, the reduced form forecasts do not seem to suffer from the persistent over-prediction that has plagued the Federal Reserve model recently.

These forecasts are based on a dynamic specification that was found to be optimal for the Federal Reserve model rather than the model in this paper. Therefore, it is still possible that we can improve on the forecasts for the reduced form model by treating the dynamics differently. To investigate this, we tried several dynamic specifications and discovered that a relatively simple specification with a lagged dependent variable and a minimal number of lags on the other right hand side variables generally produced the best forecasts. A typical example of the estimates from such a specification is presented in tables 8 and 9, along with the associated one-step ahead forecasts in figures 4 and 5.

The estimated long run multipliers in tables 8 and 9 are similar in magnitude to the corresponding estimates in tables 6 and 7.[15] The main difference in the two estimates of the price equation is that the estimated multiplier on the exchange rate is higher in absolute value with a lagged dependent variable (estimate is -0.481 in table 8) than without (-0.315 in table 6); and that the estimated unit labor cost multiplier is lower with a lagged dependent variable (0.316 in table 8, 0.598 in table 6). For import quantities, the oil price and investment spending multipliers are higher in absolute value with the lagged dependent variable, but otherwise the multipliers are quite similar in the two specifications. Exclusion tests once again confirm that consumption and investment are jointly significant in the price reduced form (F(2,66)=5.8, significance level = 0.005), and that unit labor costs and oil prices are jointly significant in the quantity reduced form (F(4,65)=4.74, significance level = 0.002).

Although the long run multipliers in the two specifications are quantitatively similar, the time path of the effects are different and this appears to be responsible for the improved forecasts in figures 4 and 5. These figures also present vertical bars which approximate 95 percent confidence bands for the one-step forecast errors, and thus provide an indication of the statistical accuracy of the forecasts. The larger confidence bands for the import quantity forecasts basically reflect a poorer fit of the import equation in sample (for example, the estimate of σ in table 9 is higher (0.034) than in table 8 (0.011)). The figures show that the actual data typically fall within these confidence bands, with the exception of the last quarter of 1990, when temporarily high oil prices cause the forecasting equation to predict higher import prices and lower import quantities than actually occurred. To the extent that foreign firms perceived this oil shock (associated with the Gulf war) as having less permanence that earlier oil shocks, the actual supply curve would have shifted to the left by less than the reduced form estimates would predict, and thus explain the over-prediction of import prices and the under-prediction of import quantities.

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[15] In the specification in tables 6 and 7, with no lagged dependent variable, the long rum multipliers are given by the sum of the coefficients on any variable. With a lagged dependent variable, the multiplier is the sum of the coefficients divided by one minus the estimated coefficient on the lagged dependent variable.

Taking the forecast period as a whole however, there is no statistical evidence that these reduced form equations systematically mis-predict either import prices or quantities. To see this formally, the figures also display the p-values for Chow tests of the null that the mean forecast error is 0, and in both cases one cannot reject this hypothesis.

The reduced form framework for analyzing import prices and quantities also enables a new cut at the issue of the extent to which exchange rate changes are "passed through" to import prices. In the limiting case where import goods are perfect substitutes in demand for domestic goods, many models predict full pass through: a one percent change in the exchange rate results in a one percent change in import prices. There are also some models where goods are imperfect substitutes which predict full pass through, such as equation (6) when import prices do not interact with import quantities. But in the more general case of imperfect substitution, there is no presumption that pass through needs to be complete.

Traditionally, empirical studies have analyzed this question with partial equilibrium price setting equations such as (5) or (6), and more general equilibrium issues have been assumed away. The pass through elasticity is typically defined as the estimated coefficient on the exchange rate in an import price equation. The model in this paper is also partial equilibrium in that we model only one market, but it is a step towards more generality because we model the interaction between prices and quantities. A natural definition of pass through in this setting would be given by the reduced form effect on equilibrium import prices of a change in the nominal exchange rate. The reduced form estimates already reported in this paper indicate a pass through elasticity defined in this way of -0.3 to -0.5, which is generally closer to zero than the estimates in the literature based on partial equilibrium pricing equations.

The pass through issue became a focus of research in the late 1980's because early evidence seemed to indicate that there was a structural break in the pass-through relationship (i.e. import prices failed to rise "enough" in response to the depreciation of the dollar that began in 1985). Furthermore, given the practice of regressing import quantities on import prices, this also seemed to explain the failure of imports to fall "enough" following the dollar's depreciation. This, in turn, also seemed to account for the stubborn persistence of the U.S. trade deficit. The evidence in this paper that import prices and quantities can be forecasted fairly well partly undercuts the principal motivation for pass through studies, but it is still of interest to see if there remains a structural break in the pass through elasticity as defined here.

To check this, recursive estimates of the reduced form exchange rate effect in the import price equation are plotted in figure 6, along with the 95 percent confidence regions for each estimate. The plotted effect is the sum of four coefficients on the exchange rate (contemporaneous plus three lags) in an import price reduced form similar to that in table 6. Increasing the sample by one observation each period has the expected effect of reducing the estimated standard error over time, so that the confidence intervals exhibit a cone-like pattern when looking from left to right. Although there is a slight drift towards zero in the estimated exchange rate effect, the drift is not large and it is not obvious that it is statistically significant when considered in light of the estimated standard error. Overall, although the exchange rate itself was highly variable in the 1980s, the estimated effect on import prices seems relatively stable in contrast.

5. Error Correction Representation and Cointegration.

The model in this paper predicts that there should be a pair of long run equilibrium relationships between each of the endogenous variables and the vector of exogenous variables. If this is true, we should expect to find statistical evidence of cointegration between the endogenous and exogenous variables. On the other hand, the model itself is silent about the speed at which the endogenous variables adjust to a new long run equilibrium after an exogenous shock. To test for cointegration, and to estimate the speed of adjustment, the reduced form of the model was re-estimated within an error correction framework, since this framework is capable of handling both questions.

To illustrate briefly the interpretation of error correction models, consider the case of two variables, x and y, which are cointegrated with cointegrating vector [1 -γ]. Although the idea of cointegration does not imply causality, assume for illustration that x is endogenous and y is exogenous. The long run equilibrium is said to be given by x = γy, and therefore x - γy measures the long run disequilibrium. One example of an error correction representation would be

$$\Delta x_t = \alpha_0 + \alpha_1 \Delta y_t + \theta(x_{t-1} - \gamma y_{t-1}) + u_t \qquad (11)$$

where α_1 measures the immediate, or short run, effect of shocks to y on x, and where θ measures the extent to which the change in x in a given period responds to disequilibrium in the previous period (in this sense it measures the speed of adjustment). If x and y are cointegrated with cointegrating vector [1 -γ], then θ should be negative and significant. Since the Engle-Granger representation theorem, Engle and Granger (1987), has established the isomorphism between the existence of an error correction representation and cointegration, examining the significance of θ in (11) is a valid test for cointegration. The null hypothesis is that θ=0, or that x and y are not cointegrated with cointegrating vector [1 γ]. Further, Dolado, Ericsson and Kremers (1992) show that this test for cointegration can be arbitrarily more powerful than the two step test proposed in Engle and Granger (1987).

The estimated error correction models are presented in tables 10 and 11. In both the price reduced form equation in table 10 and the quantity reduced form in table 11, the coefficient on the error correction term provides statistical evidence that these variables are cointegrated.[16] For the price equation, the cointegrating vector for the variables [ln(P_m) ln(C) ln(I) ln(CPI) ln(E) ln(W) ln(P_{oil}) 1] is [-1.0 0.377 0.327 0.023 -0.648 0.196 0.188 -0.450]. This vector was obtained by regressing ln(P_m) on its own lag and the log levels of all the other exogenous variables and then solving numerically for the long run solution. For the import quantity variable, the cointegrating vector for [ln(Q_m) ln(C) ln(I) ln(CPI) ln(E) ln(W) ln(P_{oil}) ln(Dock) 1], obtained with a similar first stage regression is [-1.0 1.866 0.430 0.513 0.392 -0.539 -0.056 1.913 -13.675].

The estimates of θ indicate that prices respond more slowly than quantities to disequilibria. For example, with the estimate of θ=-.166 in the price equation, it would take prices 8 quarters to close 75 percent of a disequilibrium, ceterus paribus. In contrast, import quantities would achieve the same adjustment in 3 quarters.

6. Conclusions.

This paper documents that a textbook, supply and demand, simultaneous equations model of import prices and quantities can explain many aspects of import price and quantity behavior over the past 25 years, appears to forecast better than standard trade equations, and the instruments we use appear to be valid instruments. On the negative side, although the demand equation and the two reduced form equations satisfy nominal homogeneity restrictions, the supply equation does not. One possible explanation for this is that foreign suppliers do not believe that exchange rate shocks have the same permanence as price or wage shocks. Overall, however, the findings reported in this paper show that a classical simultaneous equations model can expalin the behavior of non-oil import prices and quantities

[16] Dolado, Ericsson and Kremers (1992) show that the t-statistic on θ varies from the Dickey-Fuller distribution to the standard normal distribution depending on the variance of $(\alpha_1-1)\Delta y$ relative to the variance of u. MacKinnon's (1990) 5% critical value for the Dickey-Fuller statistic for N=93 is -4.89, so the variables appear cointegrated even with the higher Dickey-Fuller critical value.

farily successfully.

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Table 1

Instrumental Variables Estimates of the Import Demand Function.

(Static Model)

Dependent Variable: Ln(Real non-oil imports)

Variable	Estimated Coefficient	Conventional Standard Error	HSC Robust Standard Error
Constant	-10.458	0.714	-
Ln(Import Price)	-0.862	0.084	0.155
Ln(Real Consumption)	1.569	0.197	0.288
Ln(Real Investment)	0.568	0.086	0.110
Ln(Real Government Spending)	-0.144	0.148	0.209
Ln(CPI)	0.834	0.093	0.282
RBAR2	0.991		
σ	0.044		
DW	1.354		
N-K	93		

This regression uses quarterly data between 1967:1 and 1991:3. The instruments for the endogenous import price variable are the three variables which enter the supply function but do not enter the demand function: the (natural) log of the exchange rate, the log of the foreign unit labor cost index, and the log of the oil price index expressed in foreign currency units. The robust standard errors are robust to serial correlation and heteroscedasticity and are calculated in the manner recommended by Wooldridge (1989), which is similar in spirit but computationally simpler than the errors in, for example, White (1984).

Table 2

Instrumental Variables Estimates of the Import Supply Function.

(Static Model)

Dependent Variable: Ln(Real non-oil imports)

Variable	Estimated Coefficient	Conventional Standard Error	Robust Standard Error
Constant	-7.298	0.759	-
Ln(Import price)	3.970	0.529	1.769
Ln(Exchange rate)	1.945	0.184	1.473
Ln(Unit labor cost)	-1.593	0.500	1.459
Ln(Oil Price)	-0.679	0.047	0.182
Ln(dock strike dummy)	0.653	0.552	0.132
RBAR2	0.927		
σ	0.127		
DW	0.551		
N-K	93		

This regression uses quarterly data between 1967:1 and 1991:3. The instruments for the endogenous import price variable are three variables which enter the demand function but do not enter the supply function: the (natural) log of real consumption spending, the log of real investment spending, and the log of the U.S. consumer price index. The goverment spending variable is not used as an instrument because it has a negative sign and is insignificant in the demand function. The robust standard errors are robust to serial correlation and heteroscedasticity and are calculated in the manner recommended by Wooldridge (1989), which is similar in spirit but computationally simpler than the errors in, for example, White (1984).

Table 3

Alternative instrumental variables estimates of the slopes of the demand and supply curves

Estimates of the Inverse Demand Slope ($\hat{\alpha}_1$)

Instrument List			Estimate	s.e.	Test of Over-identifying Restrictions χ^2	s. level
ln(E)	ln(W)	$\ln(P_{oil})$	-0.836	0.116	1.74	[0.419]
ln(E)	ln(W)	-	-0.886	0.123	0.18	[0.670]
ln(E)	-	$\ln(P_{oil})$	-0.816	0.118	0.35	[0.554]
-	ln(W)	$\ln(P_{oil})$	-0.939	0.166	0.90	[0.343]
ln(E)	-	-	-0.860	0.138	-	-
-	ln(W)	-	-0.932	0.165	-	-
-	-	$\ln(P_{oil})$	-0.582	0.427	-	-

Estimates of the Inverse Supply Slope (β_1)

Instrument List			Estimate	s.e.	Test of Over-identifying Restrictions χ^2	s. level
ln(C)	ln(I)	ln(P)	5.000	1.716	5.77	[0.056]
ln(C)	ln(I)	-	6.422	2.389	2.64	[0.104]
ln(C)	-	ln(P)	8.518	3.780	0.86	[0.355]
-	ln(I)	ln(P)	6.764	2.172	0.05	[0.946]
ln(C)	-	-	10.116	5.063	-	-
-	ln(I)	-	6.827	2.366	-	-
-	-	ln(P)	6.601	2.961	-	-

The regressions from which these estimates are taken are identical to those reported in tables 1 and 2 except that these regressions allow for an AR1 error structure and of course use alternative instruments.

Table 4

Instrumental Variables Estimates of the Import Demand Function.
(Dynamic Model)

Dependent Variable: Ln(Real non-oil imports)

Variable	Number of Lag Terms	Estimated sum of Coefficients	T or F Statistics
Ln(Import Price)	0	-0.788	-4.294
Ln(Real Consumption)	1	1.380	9.951
Ln(Real Investment)	1	0.606	9.951
Ln(Real Government Spending)	1	-0.020	0.723
Ln(CPI)	2	0.784	17.869
RBAR2	0.993		
σ	0.039		
RHO	0.341		
N-K	84		

This regression uses quarterly data between 1967:1 and 1991:3. The instruments for the endogenous import price variable are the log of the current and twice lagged values of the exchange rate index, the log of current and twice lagged values of the foreign unit labor cost index, and current and twice lagged values of the log of the oil price index expressed in foreign currency units. The table reports maximum likelihood estimates of a model with an AR1 error structure. For the import price variable which is not lagged, the reported long run effect reported in column 2 is of course just the simple coefficient and column 3 contains the associated T-statistic. For the other variables with lags, the sum of the coefficients is reported in column 2 and the associated F-statistic is reported in column 3 to test whether current and lagged values of the indicated regressor can be jointly excluded from the regression. The 5 percent critical values for the relevant F statistics are F(2,84)=3.11, and F(3,84)=2.72. The estimated constant term is not reported.

Table 5

Instrumental Variables Estimates of the Import Supply Function.
(Dynamic Model)

Dependent Variable: Ln(Real non-oil imports)

Variable	Number of Lag Terms	Estimated long run effect	T or F Statistics
Ln(Import price)	0	4.185	4.211
Ln(Exchange rate)	2	2.219	6.623
Ln(Unit labor cost)	2	-1.899	2.939
Ln(Oil Price)	2	-0.598	6.868
Ln(dock strike dummy)	0	0.860	3.739
RBAR2	0.979		
σ	0.066		
RHO	0.884		
N-K	83		

This regression uses quarterly data between 1967:1 and 1991:3. The instruments for the endogenous import price variable are the current and lagged values of the log of real consumption spending, current and lagged values of the log of real investment spending, and current and twice lagged values of the log of the U.S. consumer price index. The goverment spending variable is again not used as an instrument because it has a negative sign and is insignificant in the demand function. The table reports maximum likelihood estimates of a model with an AR1 error structure. For the two variables which are not lagged, the reported long run effect reported in column 2 is of course just the simple coefficient and colum 3 contains the associated t-statistic. For the other variables with lags, the sum of the coefficients is reported in column 2 and the associated F-statistic is reported in column 3 to test whether current and lagged values of the indicated regressor can be jointly excluded from the regression. The 5 percent critical value for the relevant F statistic is F(3,83)=2.72. The estimated constant term is not reported.

Table 6

Reduced Form Forecasting Equation: Import Prices

Dependent Variable: Ln(Non-oil, non-computer, import price)

Variable	Number of Lag Terms	Estimated effect	F Statistic
ln(Real Consumption)	0	0.2307	1.2617
ln(Real Investment)	0	0.0973	1.6118
ln(CPI)	3	0.2023	7.1643
ln(Unit Labor Costs)	3	0.5982	14.3830
ln(Exchange Rate)	7	-0.3146	8.0527
ln(P_{oil})	3	0.0815	4.6208
R2		0.999	
σ		0.015	
DW		1.162	

This is an OLS regression using quarterly data between 1967:1 and 1986:4. The specification mimicks that of Helkie and Hooper (1988), and the out-of sample forecasts from this equation and the Helkie-Hooper model are compared in figure 2. The numbers reported in the third column under "estimated effect" are either simple regression coefficients or sums of regression coefficients. The F statistic in the next column tests whether all coefficients on a given variable can be set to 0.

Table 7

Reduced Form Forecasting Equation: Import Quantity

Dependent Variable: Ln(Non-oil, non-computer, imports)

Variable	Number of Lag Terms	Estimated effect	F Statistic
ln(Real Consumption)	0	1.9149	4.3702
ln(Real Investment)	0	0.3807	2.4917
ln(CPI)	0	0.4340	4.2048
ln(Unit Labor Costs)	0	-0.5229	-2.5750
ln(Exchange Rate)	7	0.3245	2.6247
ln(P_{oil})	0	-0.0198	-0.6047
R2		0.984	
σ		0.047	
DW		1.534	

This is an OLS regression using quarterly data between 1967:1 and 1986:4. The specification mimicks that of Helkie and Hooper (1988), and the out-of sample forecasts from this equation and the Helkie-Hooper model are compared in figure 3. The numbers reported in the third column under "estimated effect" are either simple regression coefficients or sums of regression coefficients. The F statistic in the next column tests whether all coefficients on a given variable can be set to 0.

Table 8

Reduced Form Forecasting Equation: Import Prices

Dependent Variable: Ln(Non-oil Import Price)

Variable	Number of Lag Terms	Estimated effect	F Statistic
Lagged Dependent Variable	-	0.661	7.427
Ln(Real Consumption)	0	0.073	0.446
Ln(Real Investment)	0	0.048	1.482
Ln(CPI)	1	0.067	1.584
Ln(Exchange rate)	2	-0.163	10.382
Ln(Unit labor cost)	1	0.107	8.385
Ln(Oil Price)	1	0.041	10.877
R2		0.992	
σ		0.011	
Chow test for Ho: mean forecast error = 0 (p-value)		0.243	

This is an OLS regression using quarterly data between 1967:1 and 1986:4. One-step ahead forecasts from this model for the period 1986:1 to 1991:3 are presented in figure 2. Since there are 19 quarters in the forecast period, there are 19 forecast errors and the reported Chow test tests whether the mean of these forecast errors is 0. The numbers reported in the third column under "estimated effect" are either simple regression coefficients or sums of regression coefficients. The F statistic in the next column tests whether all coefficients on a given variable can be set to 0.

Table 9

Reduced Form Forecasting Equation: Import Quantity

Dependent Variable: Ln(Non-oil Imports)

Variable	Number of Lag Terms	Estimated effect	F Statistic
Lagged Dependent Variable	-	0.376	4.642
Ln(Real Consumption)	0	1.099	9.531
Ln(Real Investment)	0	0.342	8.255
Ln(CPI)	1	0.279	4.382
Ln(Exchange rate)	2	0.273	5.389
Ln(Unit labor cost)	1	-0.283	1.340
Ln(Oil Price)	1	-0.065	1.774
Ln(Dock Strike Variable)	0	1.036	46.016
R2		0.993	
σ		0.034	
Chow test for Ho: mean forecast error = 0 (p-value)		0.863	

This is an OLS regression using quarterly data between 1967:1 and 1986:4. One-step ahead forecasts from this model for the period 1986:1 to 1991:3 are presented in figure 2. Since there are 19 quarters in the forecast period, there are 19 forecast errors and the reported Chow test tests whether the mean of these forecast errors is 0. The numbers reported in the third column under "estimated effect" are either simple regression coefficients or sums of regression coefficients. The F statistic in the next column tests whether all coefficients on a given variable can be set to 0.

Table 10

Error-Correction Representation of the Reduced Forms: Price Equation

Dependent Variable: ΔLn(Non-oil Import Price)

Variable	Estimated short run effect	T Statistic
ΔLn(Real Consumption)	0.157	0.674
ΔLn(Real Investment)	0.044	0.703
ΔLn(Real Government Spending)	-	-
ΔLn(CPI)	0.080	0.343
ΔLn(Exchange rate)	-0.187	5.729
ΔLn(Unit labor cost)	0.354	3.476
ΔLn(Oil Price)	0.044	4.387
Error Correction Term	-0.166	-5.572
RBAR2	0.640	
σ	0.011	
DW	1.529	

This is an OLS regression using quarterly data between 1967:1 and 1991:3. The error correction term is interpreted as a measure of the previous period's disequilibrium, and the coefficient on this term indicates the amount of adjustment to a given period's disequilibrium that occurs in the following period, ceterus paribus. Complete adjustment in one period would be indicated by a coefficient of -1.0. In this regression, the error correction term is $\ln(P_m)_{t-1}-X_{t-1}'\beta$, where X_{t-1} is the vector of lagged exogenous variables in log levels, ordered as follows (all variables in logs): $X'=[C\ I\ CPI\ E\ W\ P_{oil}\ 1]$, and where β is the associated vector of coefficients giving the long run effects of these variables: $\beta'=[0.377\ 0.327\ 0.023\ -0.648\ 0.196\ 0.188\ -0.450]$. The β vector includes the point estimates of the long run multipliers from a first stage regression in log levels with a lagged dependent variable. Delta method standard errors indicate that the long run coefficients on I E and P_{oil} are statistically significant.

Table 11

Error-Correction Representation of the Reduced Forms: Quantity Equation

Dependent Variable: ΔLn(Real Non-oil Imports)

Variable	Estimated short run effect	T Statistic
ΔLn(Real Consumption)	-	-
ΔLn(Real Investment)	0.609	4.792
ΔLn(Real Government Spending)	-	-
ΔLn(CPI)	0.337	0.677
ΔLn(Exchange rate)	0.174	2.105
ΔLn(Unit labor cost)	-0.442	1.661
ΔLn(Oil Price)	-0.028	1.108
Δln(Dock strike)	1.100	13.134
Error Correction Term	-0.375	-5.123
RBAR2	0.704	
σ	0.029	
DW	1.642	

This is an OLS regression using quarterly data between 1967:1 and 1991:3. The error correction term is interpreted as a measure of the previous period's disequilibrium, and the coefficient on this term indicates the amount of adjustment to a given period's disequilibrium that occurs in the following period, ceterus paribus. Complete adjustment in one period would be indicated by a coefficient of -1.0. In this regression, the error correction term is $\ln(M)_{t-1}-X_{t-1}'\beta$, where X_{t-1} is the vector of lagged exogenous variables in log levels, ordered as follows (all variables in logs): X'=[C I CPI E W P_{oil} DS 1], and where β is the associated vector of coefficients giving the long run effects of these variables: β'=[1.866 0.430 0.513 0.392 -0.539 -0.056 1.913 -13.675]. The β vector includes the point estimates of the long run multipliers from a first stage regression in log levels with a lagged dependent variable. Delta method standard errors indicate that all long run coefficients except that on P_{oil} are statistically significant. The p-value for the P_{oil} coefficient is 0.082.

Estimated Supply and Demand Functions for Non-oil Imports

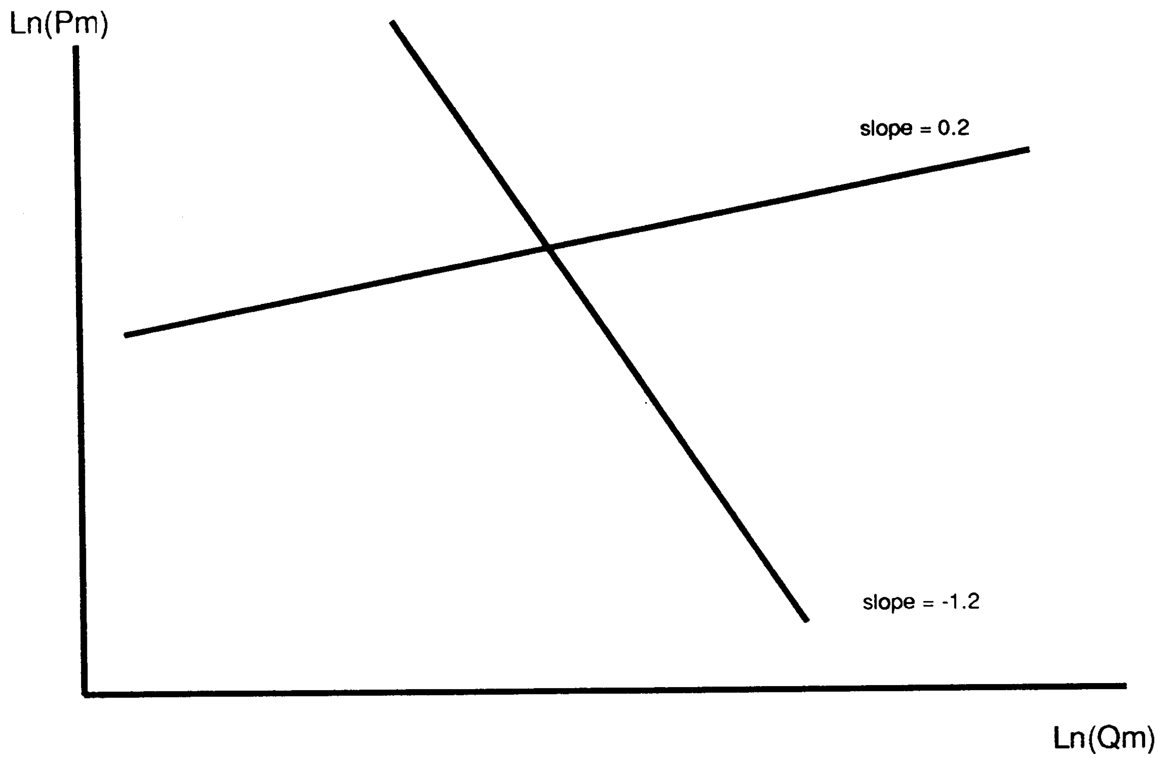
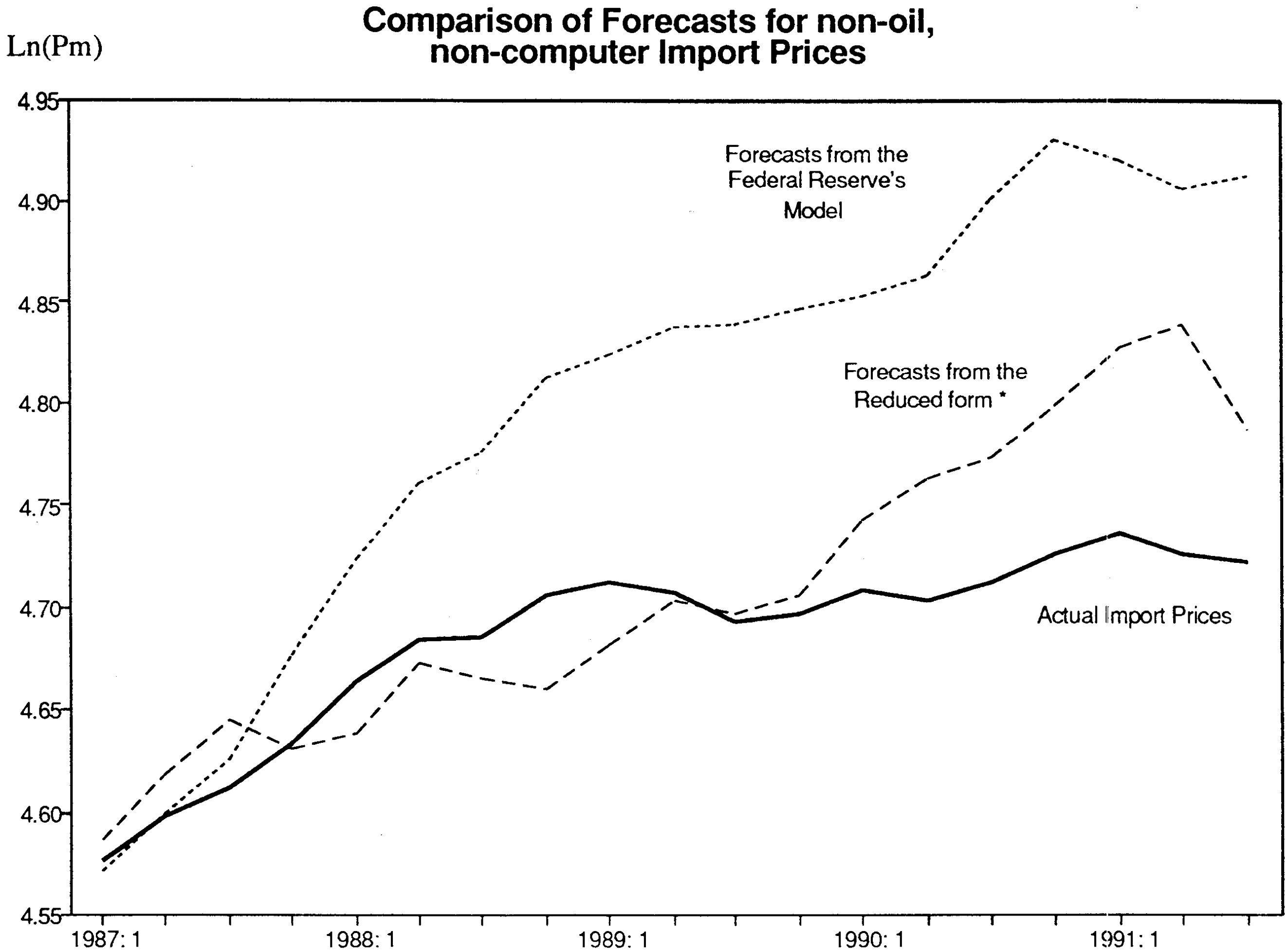
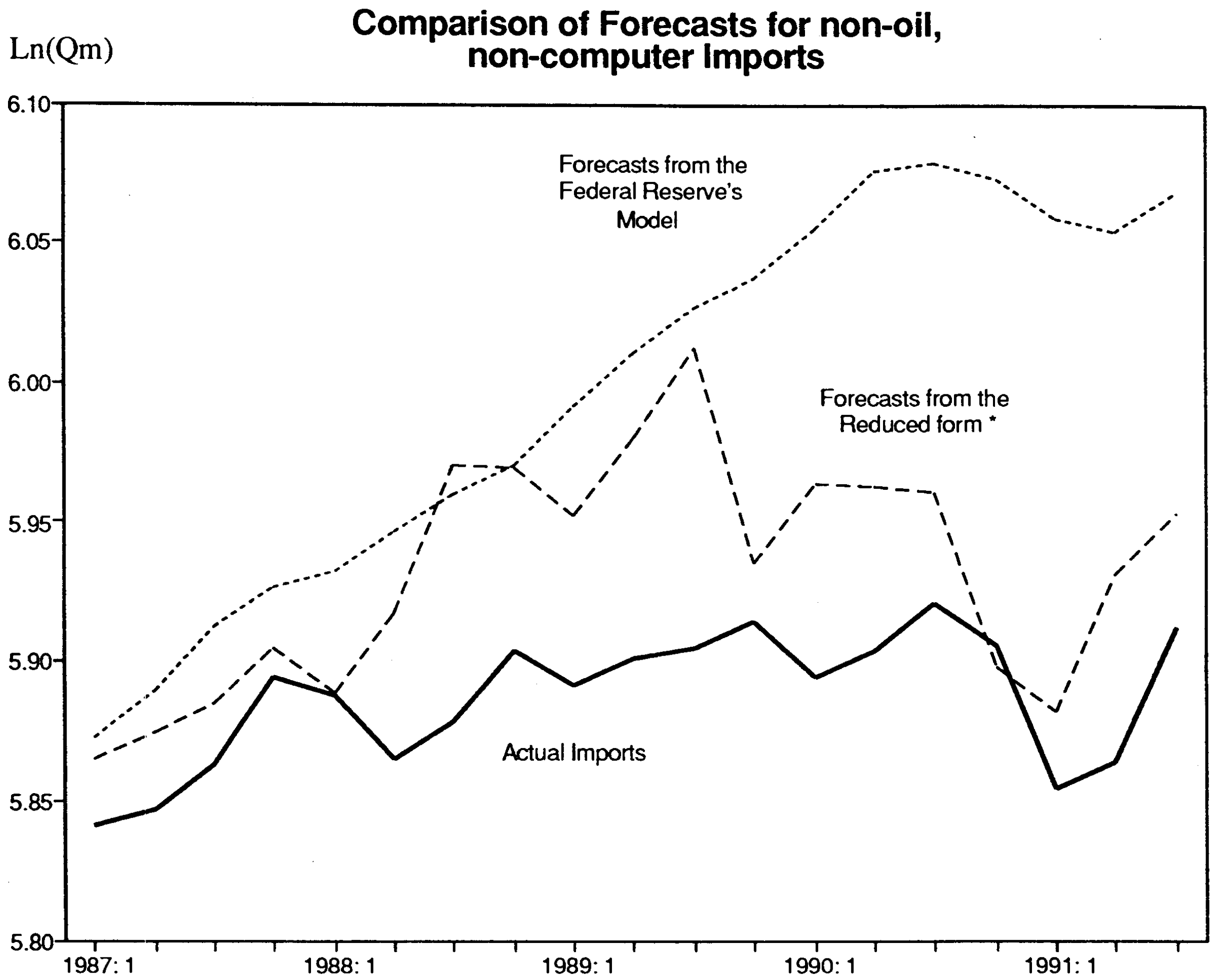


Figure 1.



* This forecast uses the variables from the reduced form model in this paper but adopts the lag specification of the Federal Reserve's model.

Figure 2.



* This forecast uses the variables from the reduced form model in this paper but adopts the lag specification of the Federal Reserve's model.

Figure 3.

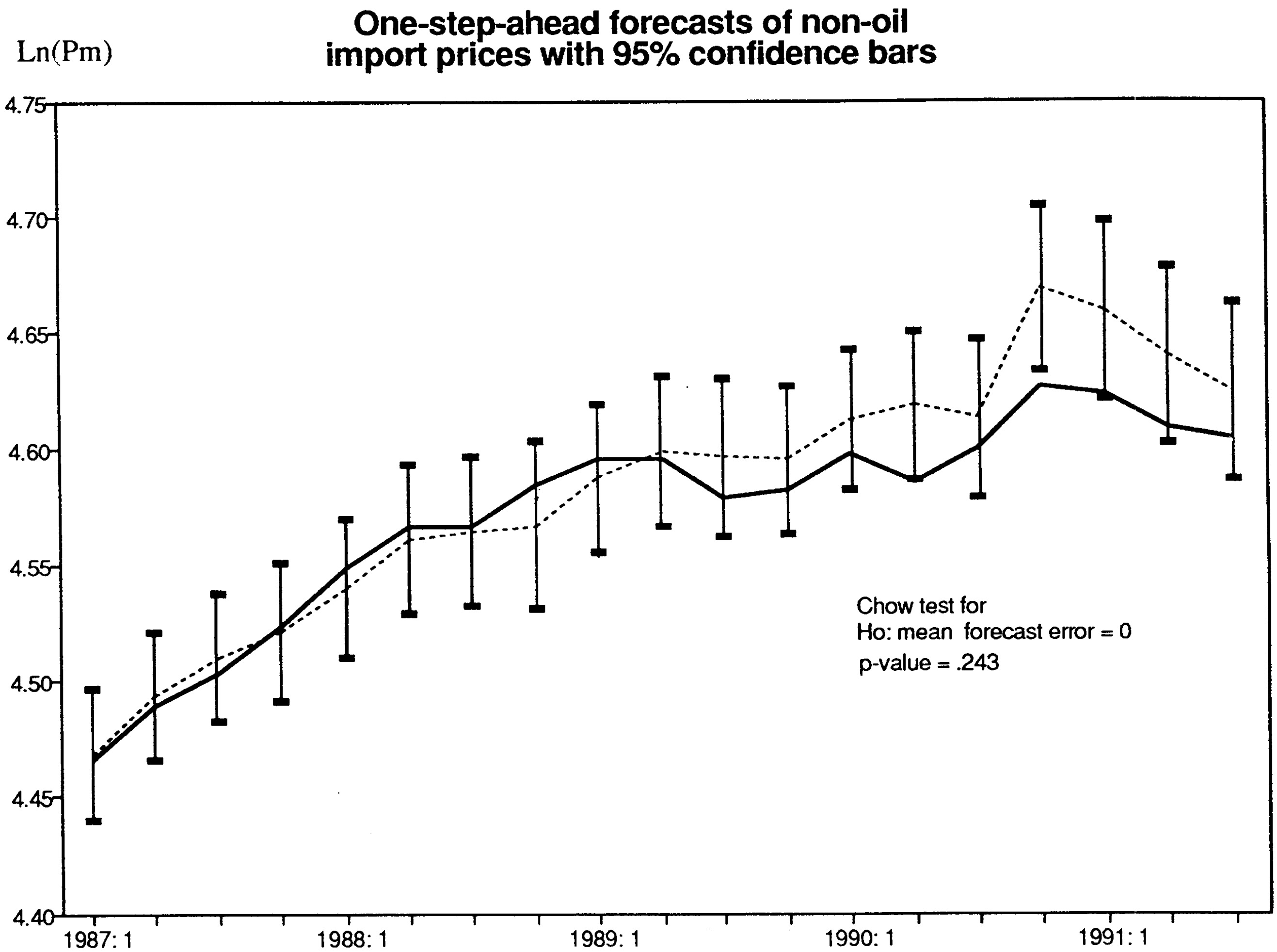

One-step-ahead forecasts of non-oil
import prices with 95% confidence bars
Ln(Pm)
4.75
4.70
4.65
4.60
4.55
4.50
4.45
4.40
1987: 1
1988: 1
1989: 1
1990: 1
1991: 1
Chow test for
Ho: mean forecast error = 0
p-value = .243

Figure 4.

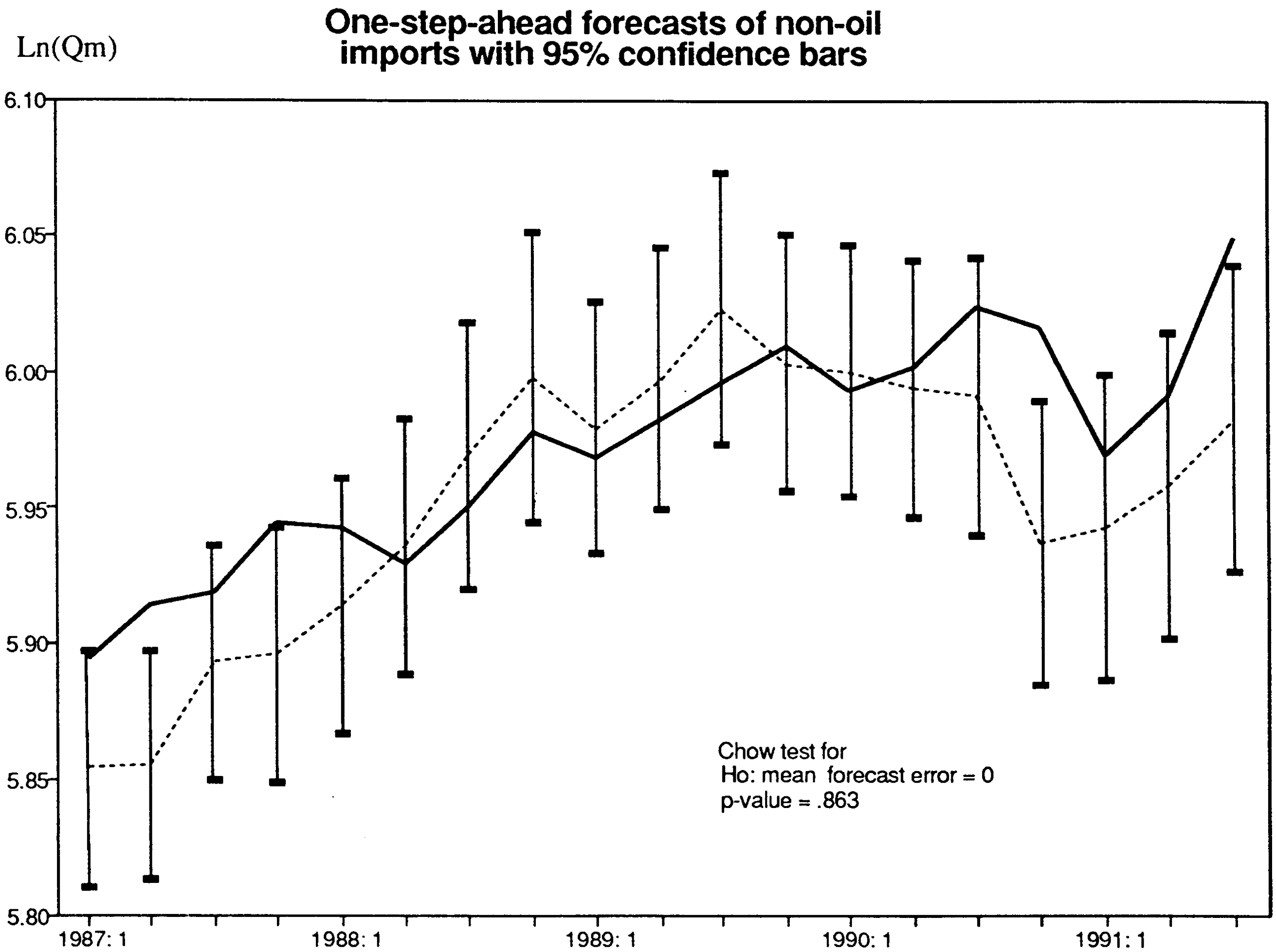

Ln(Qm)
One-step-ahead forecasts of non-oil imports with 95% confidence bars
6.10
6.05
6.00
5.95
5.90
5.85
5.80
Chow test for
Ho: mean forecast error = 0
p-value = .863
1987: 1
1988: 1
1989: 1
1990: 1
1991: 1

Figure 5.

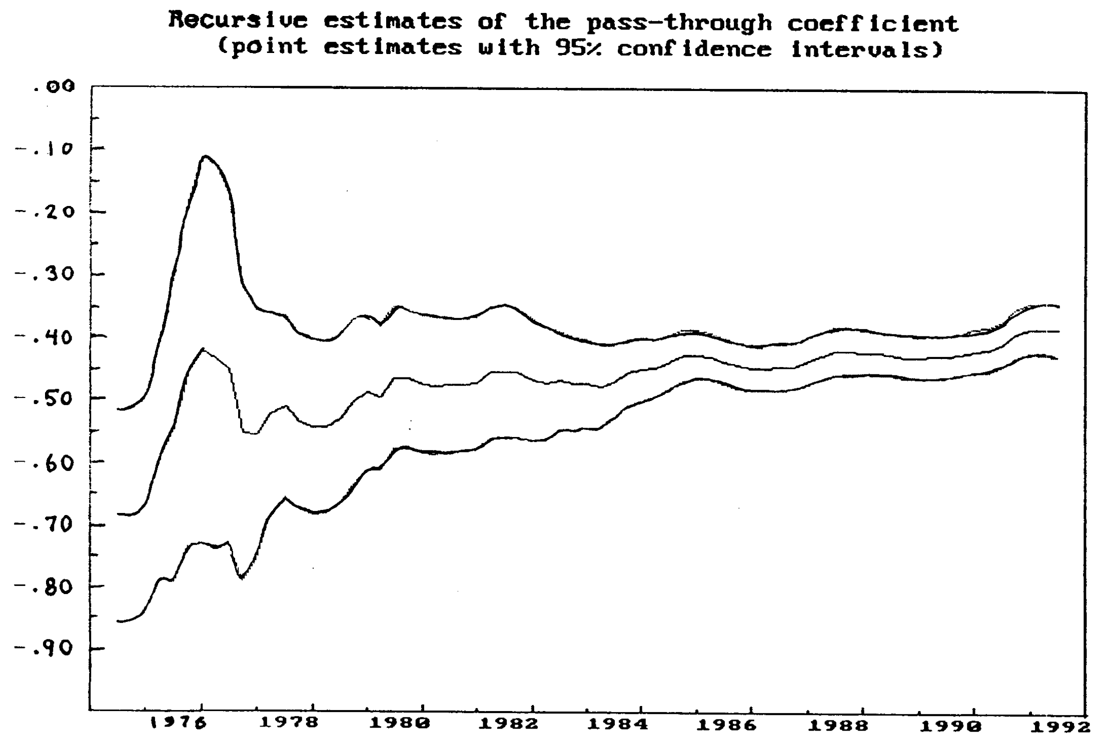

Recursive estimates of the pass-through coefficient
(point estimates with 95% confidence intervals)
.00
-.10
-.20
-.30
-.40
-.50
-.60
-.70
-.80
-.90
1976
1978
1980
1982
1984
1986
1988
1990
1992

Figure 6.

Data Appendix

	M	Pm	C	I	G	ULC	Poil	CPI	E	Dock Strike
1965:1	NA	NA	1463.40	373.60	NA	NA	NA	93.78	120.02	0.8636
	NA	NA	1480.90	384.10	NA	NA	NA	94.39	120.27	1.0195
	NA	NA	1503.10	393.50	NA	NA	NA	94.64	120.41	1.0000
	NA	NA	1540.60	400.30	NA	NA	NA	95.16	120.26	1.0000
1966:1	NA	NA	1559.60	413.40	NA	NA	NA	96.05	120.41	1.0000
	NA	NA	1566.10	403.80	NA	NA	NA	96.93	120.49	1.0000
	NA	NA	1582.00	402.10	NA	NA	NA	97.77	120.35	1.0000
	NA	NA	1587.60	385.70	NA	NA	NA	98.54	120.49	1.0000
1967:1	88.20	28.39	1600.20	377.40	670.70	36.68	13.13	98.91	120.42	1.0000
	85.50	28.37	1620.80	388.30	668.00	36.65	13.50	99.49	120.26	1.0000
	88.60	28.44	1629.40	393.20	674.10	36.87	14.18	100.40	120.34	1.0000
	96.80	28.46	1639.00	405.00	679.40	36.59	13.92	101.61	121.15	1.0000
1968:1	105.10	28.71	1672.90	413.00	688.80	36.99	13.02	102.51	122.61	1.0000
	107.90	28.91	1696.80	411.10	694.00	37.27	13.69	103.42	122.64	1.0000
	114.60	28.89	1725.20	415.80	689.00	37.33	13.30	104.92	122.64	1.0372
	113.90	29.14	1735.00	425.90	691.90	37.14	13.59	106.13	122.49	0.9798
1969:1	98.50	29.33	1754.70	437.40	685.30	37.67	13.66	107.63	122.71	0.8476
	126.30	29.55	1765.10	437.00	690.90	37.97	13.50	109.14	122.80	1.0739
	124.20	29.99	1775.00	442.80	685.20	38.51	13.27	110.63	123.68	1.0000
	119.70	30.85	1790.10	428.90	682.90	39.02	13.27	112.44	122.33	1.0000
1970:1	118.60	31.25	1800.50	426.20	676.40	40.06	13.70	114.25	122.12	1.0000
	120.50	31.79	1807.50	414.40	663.00	41.01	13.74	115.76	121.66	1.0000
	120.60	33.16	1824.70	425.00	666.90	42.19	13.93	116.96	121.23	1.0000
	123.10	33.65	1821.20	429.60	664.90	43.30	13.96	118.76	121.09	1.0000
1971:1	124.80	34.46	1849.90	440.10	659.20	43.56	14.21	119.67	120.76	1.0000
	135.40	34.20	1863.50	458.80	656.50	43.96	14.83	120.88	120.11	1.0000
	140.30	34.59	1876.90	466.80	654.20	44.77	15.33	122.07	117.94	0.9597
	126.00	34.80	1904.60	477.10	653.20	44.97	15.19	122.97	114.10	0.9066
1972:1	148.70	35.76	1929.30	495.70	657.90	45.95	15.30	123.89	109.40	1.0698
	141.60	36.57	1963.30	503.50	656.00	45.84	15.47	124.78	108.60	0.9874
	146.70	37.11	1989.10	507.80	648.50	46.53	15.58	125.67	109.04	1.0000
	153.60	37.60	2032.10	531.50	649.50	46.80	16.00	127.18	109.98	1.0000
1973:1	159.40	38.39	2063.90	554.40	652.30	47.10	16.40	128.99	104.65	1.0000
	152.30	40.95	2062.00	558.20	645.90	48.64	17.41	131.68	99.26	1.0000
	148.70	41.92	2073.70	555.70	636.80	49.91	19.17	134.39	94.43	1.0000
	148.90	43.70	2067.40	547.50	642.00	51.77	25.38	137.69	98.34	1.0000
1974:1	150.70	45.72	2050.80	533.20	648.80	52.82	53.76	141.90	104.54	1.0000
	152.50	49.52	2059.00	524.80	658.60	56.57	68.31	145.82	99.68	1.0000
	149.10	52.92	2065.50	510.90	654.20	60.08	68.65	149.70	102.12	1.0000
	141.60	55.14	2039.90	479.30	660.10	63.39	67.88	154.52	100.64	1.0000
1975:1	122.60	56.55	2051.80	447.70	659.20	66.86	67.76	157.81	95.55	1.0000
	112.90	57.14	2086.90	441.80	659.50	67.77	67.12	159.60	95.53	1.0000
	125.10	55.71	2114.40	453.70	665.40	68.89	66.59	162.88	101.53	1.0000
	132.10	55.33	2137.00	462.80	669.70	69.89	68.07	165.89	103.35	1.0000
1976:1	144.40	55.70	2179.30	482.50	665.10	70.49	70.57	167.69	104.51	1.0000
	150.20	56.70	2194.70	488.50	658.90	70.04	71.06	169.18	107.10	1.0000
	155.40	57.62	2213.00	492.00	657.00	71.33	71.49	171.86	106.74	1.0000
	158.20	57.68	2242.00	517.50	655.90	72.70	72.69	174.26	106.20	1.0000
1977:1	157.20	59.57	2271.30	538.70	659.20	72.84	75.95	177.56	105.75	1.0000
	165.50	61.30	2280.80	568.40	666.70	74.65	77.49	180.55	104.86	1.0000
	165.20	62.58	2302.60	574.30	666.00	76.05	77.68	183.24	103.38	1.0000
	171.90	62.84	2331.60	583.40	664.30	77.19	78.17	185.93	100.34	0.9550
1978:1	185.50	64.39	2347.10	589.40	666.10	77.46	77.64	188.93	95.83	1.0380
	191.80	66.70	2394.00	626.60	675.90	77.38	77.20	193.44	94.95	1.0000
	190.10	67.66	2404.50	640.90	681.80	78.53	77.09	197.92	90.10	1.0000

Data Appendix (Continued)

	M	Pm	C	I	G	ULC	Poil	CPI	E	Dock Strike
	193.50	68.73	2421.60	652.50	684.10	79.20	77.38	202.42	87.32	1.0000
1979:1	189.90	71.17	2437.90	657.30	681.20	80.66	81.34	207.53	87.82	1.0000
	194.70	72.77	2435.40	652.60	687.00	81.26	95.10	214.12	89.64	1.0000
	190.80	73.98	2454.70	661.50	693.60	82.84	122.24	221.00	86.88	1.0000
	196.90	77.70	2465.40	653.10	695.30	83.55	137.41	227.91	87.49	1.0000
1980:1	199.80	81.72	2464.60	643.40	704.70	84.51	163.32	236.88	87.53	1.0000
	190.90	83.33	2414.20	581.10	707.90	87.54	178.56	244.98	87.78	1.0000
	180.80	85.81	2440.30	581.50	701.90	90.62	182.14	249.45	85.42	1.0000
	191.20	86.93	2469.20	604.70	702.20	91.80	187.86	256.62	88.75	1.0000
1981:1	197.40	87.63	2475.50	611.20	712.20	92.70	202.08	263.52	94.13	1.0000
	205.90	87.77	2476.10	611.10	713.40	94.36	208.63	269.20	102.61	1.0000
	207.20	86.19	2487.40	608.80	711.70	95.71	194.93	276.69	109.59	1.0000
	216.40	86.55	2468.60	594.90	715.50	96.85	189.54	281.21	104.92	1.0000
1982:1	208.40	87.06	2484.00	578.30	714.70	99.13	187.40	283.64	109.44	1.0000
	212.20	86.11	2488.90	561.00	719.20	100.43	179.05	287.87	113.57	1.0000
	213.80	84.89	2502.50	544.30	724.60	101.92	182.92	292.64	119.46	1.0000
	202.40	84.59	2539.30	548.40	735.90	102.34	181.12	293.52	121.64	1.0000
1983:1	221.70	83.90	2556.50	553.20	735.30	100.77	161.85	293.81	118.56	1.0000
	231.70	83.67	2604.00	578.10	740.40	100.76	162.69	297.13	122.10	1.0000
	246.60	83.59	2639.00	608.70	751.50	100.76	166.92	300.13	127.72	1.0000
	271.90	83.27	2678.20	640.20	748.10	99.09	164.27	303.16	129.03	1.0000
1984:1	295.60	83.40	2703.80	660.10	754.10	98.88	164.59	307.39	130.32	1.0000
	308.10	83.80	2741.10	689.60	763.30	98.92	166.30	310.42	131.45	1.0000
	316.80	83.07	2754.60	700.10	766.00	98.32	163.11	313.10	140.34	1.0000
	322.10	82.39	2784.80	708.40	784.30	98.23	161.73	315.81	145.75	1.0000
1985:1	323.40	80.52	2824.90	717.80	791.50	99.05	156.38	318.84	154.84	1.0000
	333.00	80.63	2849.70	724.60	805.80	99.48	158.09	321.52	147.61	1.0000
	334.10	80.73	2893.30	719.90	825.70	100.19	150.46	323.59	137.89	1.0000
	342.60	81.95	2895.30	732.90	830.50	101.26	153.62	326.85	126.68	1.0000
1986:1	344.00	83.04	2922.40	728.20	834.90	102.91	126.28	328.64	117.83	1.0000
	357.70	83.12	2947.90	728.10	850.60	103.50	77.28	330.43	112.51	1.0000
	360.30	83.98	2993.70	723.80	871.60	104.27	67.02	332.56	106.51	1.0000
	365.60	85.25	3012.50	725.90	864.80	105.71	74.48	334.94	105.33	1.0000
1987:1	363.00	86.99	3011.50	706.80	869.10	105.52	91.75	339.21	98.33	1.0000
	370.30	89.07	3046.80	718.30	879.00	105.24	101.51	343.13	95.38	1.0000
	372.10	90.31	3075.80	733.00	884.90	104.90	105.44	346.76	97.10	1.0000
	382.00	92.08	3074.70	733.90	893.00	104.41	100.00	349.76	90.62	1.0000
1988:1	381.10	94.52	3128.20	737.70	883.70	104.54	88.55	352.52	88.45	1.0000
	375.90	96.25	3147.80	753.30	885.60	104.97	88.25	356.42	88.80	1.0000
	383.80	96.24	3170.60	758.60	883.70	105.45	82.74	360.97	95.86	1.0000
	394.60	97.91	3202.90	764.10	894.50	106.71	75.10	364.87	91.24	1.0000
1989:1	390.60	98.98	3200.90	761.90	886.90	107.22	89.84	369.09	94.22	1.0000
	396.50	98.96	3208.60	758.50	898.30	108.41	106.27	374.86	98.61	1.0000
	401.80	97.39	3241.10	756.60	907.40	110.03	97.21	377.91	98.83	1.0000
	407.20	97.70	3241.60	749.20	908.90	111.86	102.71	381.54	95.73	1.0000
1990:1	400.80	99.14	3258.80	758.90	923.00	113.38	114.49	388.23	91.85	1.0000
	404.20	97.98	3258.60	743.80	928.10	115.65	96.79	392.15	91.53	1.0000
	413.10	99.51	3281.20	746.40	927.50	114.58	112.98	398.84	86.28	1.0000
	409.90	102.21	3251.80	727.80	937.90	118.26	168.91	405.55	81.74	1.0000
1991:1	391.00	101.82	3241.10	689.80	944.50	120.08	118.08	408.86	83.26	1.0000
	399.80	100.40	3252.40	686.80	944.30	121.81	100.58	411.29	91.49	1.0000
	423.80	100.00	3271.20	686.50	936.10	122.35	100.19	414.04	91.77	1.0000
	430.70	NA	3269.50	686.20	NA	122.88	105.21	417.71	86.65	1.0000

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