Import Price Uncertainty and the Distribution of Income

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Abstract

In this paper, we estimate oil and non-oil import demand functions for the United States under the assumption that import prices are uncertain. Both import demand functions are formally derived from an expected utility maximization problem, treating imports as inputs to the technology. The model allows us to test for risk aversion and to assess the impact of uncertainty on the volume of imports, gross output and the distributional of income. We find that uncertainty leads to a reduction in welfare, imports and gross output. Moreover, it hurts labor relatively much more than capital. The impact of uncertainty, however, is found to be quite small.

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1 Introduction

The purpose of this paper is to analyze the effects of uncertain import prices on the volume of aggregate imports and the distribution of income in the United States during the postwar period. It is often argued that one reason that firms are reluctant to engage in international trade is that foreign activities are associated with greater uncertainty than domestic activities. Foreign markets may involve greater uncertainty than domestic ones, for a variety of reasons. In this study we focus on one possible reason; import-price uncertainty. Given the importance of imports of foreign oil for the U.S. economy and since much of the volatility of import prices is due to the volatility of oil prices, we disaggregate imports into petroleum products and other goods and services.

Import prices may be uncertain for a number of reasons. One obvious explanation is exchange-rate uncertainty. Another is that the foreign-currency prices of imported goods themselves are uncertain due to the long leads and lags (which are common in international trade), distance, cultural and language barriers and general unfamiliarity with foreign conditions. Hence, importers may not know with certainty the landed prices of foreign goods when import decisions are made. Since uncertainty affects production decisions, nations might fail to achieve the full potential gains from trade. This raises the question of the distributional effects of uncertainty. Namely, how is this implicit cost shared between the domestic factors of production? Our empirical results show that, although the cost of uncertainty is relatively small for most observations, it is overwhelmingly borne by labor.

Foreign trade under uncertainty has been the subject of numerous studies in the theoretical trade literature.[1] Over the last two decades, there has also been a number of empirical papers seeking to assess the quantitative impact of uncertainty on the volume of trade.[2] Most of this work has focused on exchange-rate uncertainty and was undertaken after the collapse of the Bretton-Woods fixed exchange-rate system, in response to a popular belief that the exchange-rate uncertainty introduced by the switch to flexible rates is a deterrent to international trade.

The evidence regarding the impact of exchange-rate uncertainty on the volume of trade is rather inconclusive. This may not be entirely surprising given that this type of uncertainty can be hedged, albeit at some cost, in the forward exchange markets.[3] However, since this cost is itself a function of exchange-rate volatility, exchange-rate uncertainty may have an indirect

[1]See Pomery (1984) for a survey. Much of the theoretical literature deals with the questions of the impact of uncertainty on the patterns of trade, national welfare, and optimal tariff policy.

[2]See Hooper and Kohlhagen (1978), Cushman (1983), Akhtar and Hilton (1984), Gotur (1985), Bailey, Tavlas and Ulam (1986), Thursby and Thursby (1987), Brada and Mendez (1988), Pere and Steinherr (1989).

[3]See Ethier (1973).

impact on foreign trade.[4] Furthermore, since forward markets are most common for relatively short maturities, it may not always be practical for importers to cover themselves against exchange-rate fluctuations. In any case, as emphasized by Pere and Steinherr (1989), much of the uncertainty affecting the price of imports has to do with unexpected fluctuations in foreign prices against which there may be no shield. Thus, the issue of terms-of-trade uncertainty remains empirically relevant in spite of the emergence of modern assets and liabilities management techniques.

Most efforts of previous researchers have been directed at assessing the quantitative effects of import and/or export price uncertainty on the volume of trade. While it is generally agreed that restricting foreign trade has a negative welfare impact, it is surprising that no attempts have been made to sort out the corresponding distributional effects. Addressing this question is a major objective of this paper.

It is interesting that much of the empirical literature dealing with trade under uncertainty has evolved from the finance literature. Thus, most authors regress the volume of imports and/or exports on some measure of exchange-rate volatility (sometimes, also the level of the exchange rate). In almost every case, the functional form is either linear or loglinear. This amounts to using a rather simplistic and antiquated specification of import and/or export functions. Indeed, until about two decades ago, nearly all the empirical work on import and export determination relied on an *ad hoc* specification, where the quantities of imports and exports were written as linear or loglinear functions of relative prices and activity.[5] The shortcomings of this approach are well known. In particular, it is based on little theory, and no trade theory at all. More seriously, such demand and supply functions are not consistent with well-behaved aggregator (production or utility) functions, except in very restrictive cases. Furthermore, econometrically more efficient estimates could be obtained if the import and/or export functions were estimated together with the other demand and/or supply functions, derived from the same optimization problem. In recent years, important advances have been made in modelling imports and exports, starting with the production-theory approach pioneered by Burgess (1974).[6] Our purpose here is to examine the question of import-price uncertainty within such a rigorous framework.

The production-theory approach views imports as an input to the technology. Imports are used together with domestic factor services (labor and capital) to produce one or several

[4]See Viaene and de Vries (1992).

[5]See Leamer and Stern (1970), and Goldstein and Khan (1985) for detailed reviews of the empirical literature on import and export determination.

[6]See Woodland (1982) and Kohli (1991) for a discussion of the theory underlying this work.

outputs, which may be absorbed at home or exported to the rest of the world. This treatment of imports is consistent with the fact that the bulk of world trade is in intermediate goods and raw materials and recognizes that even most so-called 'finished' products are still subject to a number of domestic activities such as handling, transportation, insurance, banking and retailing, before reaching final demand. Thus, these goods flow through the domestic production sector, where they are combined with domestic factor services. An important share of their final price tag may, therefore, ultimately be accounted for by domestic value added.

Over the years the production-theory approach to the determination of imports has been extended in a number of directions. Kohli (1978) treated imports as a variable input, while viewing the endowments of domestic factors as given; this leads to the GNP function approach to modelling imports. Furthermore, Kohli disaggregated output and modeled the supply of exports. In Kohli (1982), labor was treated as a variable input, thus allowing foreign trade to have an impact on employment. Appelbaum and Kohli (1979) allowed for noncompetitive behavior and tested for departures from price-taking behavior. The production-theory approach has been implemented with various flexible functional forms and has been applied to a number of countries, industrialized nations as well as NDC's and LDC's.[7]

By considering the impact of import-price uncertainty, we extend the production-theory approach to modelling the demand for imports into another direction. We believe that this extension is empirically important for several reasons. First, failure to take uncertainty into account when estimating import demand functions might lead to biased estimates. Second, uncertainty must be taken into account explicitly, if we want to assess its effects on import decisions and its role as a deterrent to international trade. Third, given that welfare losses are unlikely to be distributed evenly, it is both important and interesting to identify the factors of production which are the most vulnerable to uncertainty.

The fact that we allow for two import components adds somewhat to the complexity of the analysis since we must take the correlation between the prices of oil and non-oil imports into account. At the same time, it opens up an entirely new set of interesting questions. For example, does import price uncertainty have the same distributional effects, irrespective of its source? Does the uncertainty regarding one type of import enhance or reduce the demand for the other import? Intuitively, the answer to these question will depend on the complementarity or substitutability relationship between the two imports and the domestic factors of production, the degree of uncertainty and the correlation between the two import prices.

[7]See Kohli (1991) for a review of this literature.

The remainder of this paper is organized as follows. The theoretical model is developed in the next section. The distributional effects of uncertainty are examined in Section 3. Section 4 deals with the empirical implementation of the model, Section 5 discusses the empirical findings and Section 6 provides a conclusion.

2 Theoretical Framework

Consider an economy whose technology is given by the aggregate production function:

$$y = f(x_M, x_E, x_L, x_K, t), \tag{1}$$

where y is aggregate gross output, x_M denotes the quantity of imports of non-petroleum products, x_E is the quantity of imports of petroleum products (think of 'E' as standing for energy), x_L is the input of labor services, x_K represents the input of capital services, and t is a time shift variable; production function $f(\cdot)$ is assumed to be continuous, nondecreasing, linearly homogeneous, and quasiconcave. We assume that all markets are perfectly competitive. While this assumption is not really necessary for the purpose of our analysis, it enables us to focus on the effects of uncertainty, rather than market structure.

It is, of course, possible for uncertainty to enter the problem in various ways; through output price, input prices, the price of imports, or technology. Given that local conditions are usually better known (easier to learn), it seems reasonable that foreign prices are less likely to be known with certainty. While this is the case for imports generally, it is particularly true for world oil prices, which have been subjected to several large and unexpected shocks in recent decades. Hence, we will focus in this paper on the effects of uncertain foreign prices. We assume that the prices of petroleum and non-petroleum imports, q_E and q_M respectively, are unknown when production decisions are made. Let this price vector be denoted by $q \equiv (q_{E,} q_M)$. On the other hand, the price of output (p), the rental prices of capital and labor (w_K and w_L, respectively) and technology are known. We can write the price of imports as $q_i = \overline{q}_i + e_i, \;\; i = M, E$, where e_i are random variables distributed according to the joint density function $g(e_M, e_E)$ with $E(e_i) = 0$ (so that $E(q_i) = \overline{q}_i$), $Var(q_i) = Var(e_i) \equiv \sigma_i^2$, and $Cov(q_M, q_E) = Cov(e_M, e_E) \equiv \sigma_{ME}$.

We assume that production decisions can be derived from the following aggregate expected utility maximization problem:

$$Max_{x_M, x_E, x_L, x_K} E\{U[pf(x_M, x_E, x_L, x_K, t) - q_M x_M - q_E x_E - w_L x_L - w_K x_K]\} :$$

$$q_M = \overline{q}_M + e_M, \quad q_E = \overline{q}_E + e_E, \tag{2}$$

where $U(\cdot)$ is a Von Neumann-Morgenstern utility function with $U' > 0$. Maximizing expected utility, we get the first-order conditions:

$$E\{U'(\pi)[pf_i(x_M, x_E, x_L, x_K, t) - q_i]\} = 0, \qquad i = M, E \tag{3}$$

$$E\{U'(\pi)[pf_j(x_M, x_E, x_L, x_K, t) - w_j]\} = 0, \qquad j = L, K, \tag{4}$$

where $f_h \equiv \partial f(\cdot)/\partial x_h$ ($h = M, E, L, K$) and $\pi \equiv pf(\cdot) - q_M x_M - q_E x_E - w_L x_L - w_K x_K$. The first order conditions (3) and (4) can be rewritten as:

$$pf_i(x_M, x_E, x_L, x_K, t) = \overline{q}_i + \theta_i, \qquad i = M, E \tag{5}$$

$$pf_j(x_M, x_E, x_L, x_K, t) = w_j, \qquad j = L, K, \tag{6}$$

where $\theta_i \equiv Cov[U'(\pi), e_i]/E[U'(\pi)]$. Since, the random variables e_M and e_E can be either positively, or negatively correlated, the sign of U'' is, in general, not enough to determine the signs of the θ_i[8]. In the case when the random variables are non-negatively correlated, θ_i will be positive, negative, or zero, depending on whether we risk aversion, risk affinity or risk neutrality respectively[9]. The right hand side of (5) can be thought of as the 'adjusted' price of imports. It includes the term θ_i which is the *marginal* risk premium (or the marginal cost of uncertainty). Condition (5) shows that the presence of uncertainty will generally lead the marginal product of imports to deviate from the expected marginal cost of imported products. Specifically, if θ_i is positive, (the value of) the marginal product of imports will exceed their (expected) market price.

Once the model has been estimated, the parameter estimates can be used to calculate and test for the effects of uncertain foreign prices on the inverse demand for domestic inputs and imports and on income distribution.

It is useful to note that if we denote the shadow price of import i as: $q_i^* \equiv \overline{q}_i + \theta_i$, then the first order conditions (5)–(6) can be obtained by solving the problem:

$$Max\{pf(x_M, x_E, x_L, x_K, t) - q_M^* x_M - q_E^* x_E - w_L x_L - w_K x_K\} \equiv$$
$$J(p, q_M^*, q_E^*, w_L, w_K, t). \tag{7}$$

The direct demand functions can then be obtained by applying Hotelling's Lemma to the 'shadow profit function' $J(\cdot)$[10].

[8] To see this, assume that e_i are distributed according to a bivariate normal distribution. Then, we can write the $Cov(U'(\pi), e_i) = \delta_i E\{U''(\pi)\}$ where, $\delta_i \equiv -[\sigma_h Cov(e_i, e_h) + x_i \sigma_i]$. Since we do not know the signs of the δ_i's, the signs of the θ_i's are also unknown. This problem does not arise with one random variable. For example, if only e_E is random, we have: $\delta_E = -x_E \sigma_E < 0$, and therefore with risk aversion; $\theta_E > 0$.

[9] If the two random variables are non-negatively correlated then, in the previous footnote, $\delta_i < 0$, so that with risk aversion we have $\theta_i > 0$.

[10] See Appelbaum (1993) for a discussion of dual functions under uncertainty and their properties.

3 Import Price Uncertainty and the Distribution of Income

To describe the substitution and complementarity relationships between the four inputs, we begin by defining the Hicksian elasticities of complementarity[11]:

$$\psi_{hk} \equiv \frac{f f_{hk}}{f_h f_k}, \qquad h,k = M,E,L,K, \tag{8}$$

where $f_{hk} \equiv \partial^2 f(\cdot)/(\partial x_h \partial x_k)$, and $f \equiv f(\cdot)$ for short. Quasiconcavity of the production function implies that $\psi_{hh} \leq 0$. Furthermore, $\psi_{hk} \geq 0$, if inputs h and k are Hicksian $q-$complements, and $\psi_{hk} \leq 0$, if inputs h and k are $q-$substitutes in the Hicksian sense.

The comparative statics of the model can be represented by a set of quantity elasticities of inverse demand. Logarithmically differentiating (1) and (5)–(6), we get:

$$\begin{bmatrix} \hat{y} \\ \hat{q}_M^* \\ \hat{q}_E^* \\ \hat{w}_L \\ \hat{w}_K \end{bmatrix} = \begin{bmatrix} 0 & s_M & s_E & s_L & s_K \\ 1 & \eta_{MM} & \eta_{ME} & \eta_{ML} & \eta_{MK} \\ 1 & \eta_{EM} & \eta_{EE} & \eta_{EL} & \eta_{EK} \\ 1 & \eta_{LM} & \eta_{LE} & \eta_{LL} & \eta_{LK} \\ 1 & \eta_{KM} & \eta_{KE} & \eta_{KL} & \eta_{KK} \end{bmatrix} \begin{bmatrix} \hat{p} \\ \hat{x}_M \\ \hat{x}_E \\ \hat{x}_L \\ \hat{x}_K \end{bmatrix}, \tag{9}$$

where the hats represent relative changes; s_M, s_E, s_L and s_K are the shares of non-oil imports, oil imports, labor, and capital in total costs; the η_{hk}'s represent the quantity elasticities of inverse demand, i.e.:

$$\eta_{ik} \equiv \frac{\partial \ln q_i^*(p, x_M, x_E, x_L, x_K, t)}{\partial \ln x_k}, \qquad i = M,E;\ k = M,E,L,K \tag{10}$$

$$\eta_{jk} \equiv \frac{\partial \ln w_j(p, x_M, x_E, x_L, x_K, t)}{\partial \ln x_k}, \qquad j = L,K;\ k = M,E,L,K. \tag{11}$$

It is well known that these can be obtained directly from the Hicksian elasticities of complementarity as:

$$\eta_{hk} = \psi_{hk} s_k, \qquad h,k = M,E,L,K. \tag{12}$$

The elasticities in (9) are useful to assess the impact of a change in relative input quantities on the marginal products of the four inputs. In international trade theory, however, it is

[11] We adopt the terminology of Sato and Koizumi (1973), and of Syrquin and Hollender (1982).

customary to treat domestic factor endowments and goods prices as given, and to consider domestic factor prices, output and variable input quantities as endogenous. In other words, while (9) views p, x_M, x_E, x_L and x_K as exogenous, and determines y, q_M^*, q_E^*, w_L and w_K, it might be more interesting to consider the case where p, q_M^*, q_E^*, x_L and x_K which are given, whereas the values of y, x_M, x_E, w_L and w_K are determined by the model. This is particularly true if we want to assess the distributional effect of a change in the (shadow) price of oil and non-oil imports. This suggests that it may be advantageous to use the GNP function. Using the GNP function we obtain the following set of elasticities:

$$\begin{bmatrix} \hat{y} \\ \hat{x}_M \\ \hat{x}_E \\ \hat{w}_L \\ \hat{w}_K \end{bmatrix} = \begin{bmatrix} \epsilon_{YY} & \epsilon_{YM} & \epsilon_{YE} & \epsilon_{YL} & \epsilon_{YK} \\ \epsilon_{MY} & \epsilon_{MM} & \epsilon_{ME} & \epsilon_{ML} & \epsilon_{MK} \\ \epsilon_{EY} & \epsilon_{EM} & \epsilon_{EE} & \epsilon_{EL} & \epsilon_{EK} \\ \epsilon_{LY} & \epsilon_{LM} & \epsilon_{LE} & \epsilon_{LL} & \epsilon_{LK} \\ \epsilon_{KY} & \epsilon_{KM} & \epsilon_{KE} & \epsilon_{KL} & \epsilon_{KK} \end{bmatrix} \begin{bmatrix} \hat{p} \\ \hat{q}_M^* \\ \hat{q}_E^* \\ \hat{x}_L \\ \hat{x}_K \end{bmatrix}, \tag{13}$$

where $\epsilon_{YY} \equiv \partial \ln y(p, q_M^*, q_E^*, x_L, x_K, t)/\partial \ln p$, and so on.

The elasticities shown in (13) can easily be obtained from the ones in (9).[12] Indeed, (9) can be partitioned and expressed as follows:

$$\begin{bmatrix} n_1 \\ n_2 \end{bmatrix} = \begin{bmatrix} A_{11} & A_{12} \\ A_{21} & A_{22} \end{bmatrix} \begin{bmatrix} v_1 \\ v_2 \end{bmatrix}, \tag{14}$$

where $n_1 \equiv (\hat{y}, \hat{w}_L, \hat{w}_K)'$, $n_2 \equiv (\hat{q}_M^*, \hat{q}_E^*)'$, $v_1 \equiv (\hat{p}, \hat{x}_L, \hat{x}_K)'$, $v_2 \equiv (\hat{x}_M, \hat{x}_E)'$, and the submatrices A_{11}, A_{12}, A_{21}, A_{22} are defined accordingly. We can then solve (14) for n_1 and v_2 as functions of v_1 and n_2 to yield the elasticities contained (13):

$$\begin{bmatrix} n_1 \\ v_2 \end{bmatrix} = \begin{bmatrix} A_{11} - A_{12}A_{22}^{-1}A_{21} & A_{12}A_{22}^{-1} \\ -A_{22}^{-1}A_{21} & A_{22}^{-1} \end{bmatrix} \begin{bmatrix} v_1 \\ n_2 \end{bmatrix}. \tag{15}$$

The ε_{hi}'s $(h = Y, M, E, L, K; i = M, E)$ in (13) indicate the effect of a change in the shadow prices of both types of imports on the demand for imports, the supply of output and

[12] See Kohli (1991).

factor payments. In order to separate the effects of a change in the expected price of import of type i from a change in the corresponding risk premium, we proceed as follows. From the definition of q_i^*, it can be seen that:

$$\hat{q}_i^* = (1-\delta_i)\hat{\overline{q}}_i + \delta_i\hat{\theta}_i, \tag{16}$$

where $\delta_i \equiv \theta_i/q_i^* = \theta_i/(pf_i)$. Let μ_{hi} and ϑ_{hi} ($h = Y, M, E, L, K;\ i = M, E$) be the partial elasticities of output supply, import demand and factor payments with respect to $\overline{q}_i$ and θ_i, for given values of p, x_L, x_K and q_k^* ($k \neq h$). Thus, $\mu_{YM} \equiv \partial \ln y(p, q_M^*, q_E^*, x_L, x_K, t)/\partial \ln \overline{q}_M$, $\vartheta_{YM} \equiv \partial \ln y(p, q_M^*, q_E^*, x_L, x_K, t)/\partial \ln \theta_M$, and so on. It follows from (9) and (16) that:

$$\mu_{hi} = (1-\delta)\varepsilon_{hi}, \qquad h = Y, M, E, L, K;\ i = M, E \tag{17}$$

$$\vartheta_{hi} = \delta\varepsilon_{hi}, \qquad h = Y, M, E, L, K;\ i = M, E. \tag{18}$$

so that the signs of μ_{hi} and ϑ_{hi} are the same as those of ε_{hi}. These are, therefore, important in determining the impact of uncertainty on the supply of output, the demand for imports and the distribution of income. The signs of $\varepsilon_{LM}, \varepsilon_{LE}, \varepsilon_{KM}$ and in particular, ε_{KE}, will indicate whether labor or capital suffer more from import price uncertainty. The ε_{hi}'s, in turn, depend on the Hicksian elasticities of complementarity. Indeed, take ε_{LM}, for instance. Making use of (15), it can be expressed as follows:

$$\varepsilon_{LM} = \frac{\eta_{LM}\eta_{EE} - \eta_{LE}\eta_{EM}}{\eta_{MM}\eta_{EE} - \eta_{ME}\eta_{EM}}. \tag{19}$$

Making use of (12), this becomes:

$$\varepsilon_{LM} = \frac{\psi_{LM}\psi_{EE} - \psi_{ME}\psi_{EL}}{\psi_{MM}\psi_{EE} - \psi_{ME}^2}. \tag{20}$$

The denominator of (20) is necessarily nonnegative due to the quasiconcavity of the production function. The sign of the numerator, however, is ambiguous. The own elasticity of complementarity of oil imports (ψ_{EE}) is necessarily nonpositive, but the other three elasticities could be of either sign.[13] If non-oil imports, oil imports, and labor all three are Hicksian q-complements for each other, which may be viewed as the 'normal' case,[14] then ε_{LM} is necessarily negative; that is, an increase in the price of non-oil imports, as well as an increase in non-oil import price uncertainty, would depress the wage rate. The same would be true

[13]It is well known that if there are two inputs only, these are necessarily Hicksian q-complements. That is, an increase in the use of one input necessarily raises the marginal product of the other input. If the number of inputs exceeds two, however, one cannot rule out the existence of Hicksian q-substitutes.

[14]This would necessarily be true if the production function were of the CES type.

if labor and non-oil imports were Hicksian q-complements, and if oil imports were Hicksian q-substitutes for both non-oil imports and labor. If, on the other hand, non-oil imports and labor are Hicksian q-substitutes, and if oil imports are a q-complement of either non-oil imports or labor, and a q-substitute for the other input, then ε_{LM} is positive, and an increase in q_M^* necessarily would raise the return to labor. In all other cases, the sign of ε_{LM} is uncertain and must be determined empirically. Similar considerations apply to ε_{LE}, ε_{KM}, and ε_{KE}.

4 Empirical Implementation

Having discussed the theoretical framework, we now provide an example of an empirical application of our model. In this example we apply the model to the U.S. demand for oil and non-oil imports. We use annual for the period 1952-1987. Most of the data is derived from BEA sources. Construction of the price and quantity series for gross output, labor and capital, is described in detail in Kohli (1991). The National Accounts provide price and quantity series for imports of petroleum products, but only from 1967. Data for earlier years is obtained from IMF sources. Non-oil imports are calculated as imports net of imports of petroleum products. Aggregation of gross output, labor, capital, and non-oil imports was carried out by computing Tornqvist price indexes.

4.1 Expected Utility

Given a functional form for the production function (1), if the expected prices of imports (q_M and q_E) and the marginal risk premia (θ_M and θ_E) were either known or could be treated as parameters, we could simply estimate the system of inverse demand equations (5)–(6). Using the parameter estimates, we could then compute the elasticities in (9), (13), (17) and (18). Unfortunately, $\overline{q}_i$ and θ_i are neither known, nor are they parameters.[15] To overcome these difficulties, we adopt the procedure proposed in Appelbaum (1991). Using the standard second order approximation to the expected utility function[16] we can write it as:

$$E[U(\pi)] \cong U\left[\overline{\pi} - \frac{1}{2}\alpha Var(\pi)\right]$$

$$= U\left[\overline{\pi} - \frac{1}{2}\alpha\left(\sigma_M^2 x_M^2 + \sigma_E^2 x_E^2 + 2\sigma_{ME} x_M x_E\right)\right], \quad (21)$$

[15]Both depend on the functional forms *and* the data.
[16]See Pratt (1964) and Samuelson (1970).

where $\overline{\pi} \equiv E(\pi)$ and $\alpha \equiv -\, U''(\overline{\pi})/U'(\overline{\pi})$ is the measure of absolute risk aversion. Given this approximation, the first-order conditions (5) become:

$$pf_i(x_M, x_E, x_L, x_K, t) = \overline{q}_i + \frac{\alpha(\sigma_i^2 x_i + \sigma_{ME} x_h)}{1 - \frac{1}{2}Var(\pi)(\partial\alpha/\partial\overline{\pi})} \quad , \qquad i = M, E;\ h \neq i, \tag{22}$$

so that the corresponding marginal risk premia are given by[17]:

$$\theta_i = \frac{\alpha(\sigma_i^2 x_i + \sigma_{ME} x_h)}{1 - \frac{1}{2}Var(\pi)(\partial\alpha/\partial\overline{\pi})} \quad , \qquad i = M, E;\ h \neq i. \tag{23}$$

To simplify the empirical analysis we assume constant absolute risk aversion, which implies that the denominator in (23) is equal to one, so that $\theta_i = \alpha(\sigma_i^2 x_i + \sigma_{ME} x_h)$. The advantage of this assumption is that it enables us to estimate the model without having to specify a utility function. The disadvantage is that it may bias the results. Specifically, as can be seen in equation (23), with decreasing absolute risk aversion (the standard assumption in models of choice under uncertainty, e.g., Appelbaum and Katz (1986)) the denominator is greater than one, thus, increasing the marginal costs of uncertainty (marginal risk premia). Assuming constant absolute risk aversion may, therefore, weaken the impact of uncertainty[18].

4.2 Distribution of q

While approximation (21) enables us to derive simple expressions for import inverse demand equations, it still involve the first two moments of the joint distribution of q_M and q_E, which are not known. To be able to obtain this information, we assume that expectations are rational, in the sense that expectations of the first two moments of q_M and q_E are formed from information on the process that generates the two import prices. Thus, we assume that market prices of oil and non-oil imports are given by:

$$q = q(Z, e), \tag{24}$$

where $e \equiv (e_M, e_E)'$ and Z is a vector of exogenous variables which consists of lagged import prices, a time trend (t), and a set of instrumental variables. The instrumental variables are

[17]As can be seen in (23), with non-negatively correlated random variables and non-increasing absolute risk aversion, the marginal risk premia always have the same sign as α.

[18]To avoid the need to use an approximation to the expected utility function with constant absolute risk aversion, it is possible to use the dual function (indirect utility function) corresponding to problem (2). This dual function depends on the moments of the distribution function and summarizes all the properties of the underlying direct utility function. It is, therefore, not necessary to make assumptions regarding the properties of U. The import demand functions can then be, simply, obtained by Roy's identity. The disadvantage of this method is that the resulting system of equations is, somewhat, more complicated. For a discussion of such applications of duality under uncertainty see Appelbaum (1993).

included in order to take into account the possible endogeneity of import prices, given that the United States can hardly be viewed as a *small* open economy.[19] We specify the following VAR(1), ARCH(1) model:[20]

$$q_{Mt} = a_{M0} + a_{M1} q_{Mt-1} + a_{M2} q_{Et-1} + a_{MT}\ t + \sum_{i=1}^{3} a_{Mz_i}\ z_{it} + e_{Mt} \tag{25}$$

$$q_{Et} = a_{E0} + a_{E1} q_{Mt-1} + a_{E2} q_{Et-1} + a_{ET}\ t + \sum_{i=1}^{3} a_{Ez_i}\ z_{it} + e_{Et} \tag{26}$$

where the t subscript denotes the time period and z_1, z_2, z_3 are the first three principle components of the set of instrumental variables (which, together, explain 99% of the variation)[21]. We assume that errors $(e_{Mt}, e_{Et})'$ are distributed according to a bivariate normal distribution, with $E(e_{it}) = 0$. To obtain time varying values for the variances and correlation we assume that $(e_{Mt}, e_{Et})'$ follow a bivariate ARCH(1) process with $Var(e_{it}) \equiv \sigma_{it}^2 = b_{i0} + b_{i1} e_{it-1}^2 \quad (b_{i0} \geq 0, b_{i1} \geq 0;\ i = M, E)$ and correlation, $\rho_t = c_0 + c_1 \frac{e_{Mt-1} e_{Et-1}}{\sigma_{Mt-1} \sigma_{Et-1}}$. Price equations (25) and (26) are estimated by maximum likelihood, subject to the bivariate ARCH(1) specification. This yields estimates of the first two moments of the joint distribution of q: $\tilde{\bar{q}}_{Mt}, \tilde{\bar{q}}_{Et}, \tilde{\sigma}_{Mt}^2, \tilde{\sigma}_{Et}^2$, and $\tilde{\rho}_t$[22].

4.3 Production Function

We assume that the production function has the following Translog form:

$$\ln y = \beta_0 + \sum_h \beta_h \ln x_h + \frac{1}{2} \sum_h \sum_k \phi_{hk} \ln x_h \ln x_k + \sum_h \phi_{hT} lnx_h t +$$

$$\beta_T t + \frac{1}{2} \beta_{TT} t^2, \qquad h, k = M, E, L, K, \tag{27}$$

ξ where $\sum \beta_h = 1, \phi_{hk} = \phi_{kh}, \sum \phi_{hk} = 0$, and $\sum \phi_{hT} = 0$.

[19] We use the instruments used by Kohli (1991). They consist of: time trend, time trend squared, U.S. population, household savings as a ratio of disposable income, the U.S. discount rate, U.S. government purchases as a ratio of GNP, and the population of three important trading partners of the United States (Canada, Japan, and the United Kingdom); sources are given in Kohli (1991).

[20] See Engle (1982). See Appelbaum (1993) for an application of a multivariate ARCH model in the context of production under uncertainty.

[21] The first three principle components are used in order to reduce the number of parameters. Since they explain 99% of the variation, this does not seem to be too costly.

[22] Note that the specification in equations (25) and (26) allows for uncertainty in import prices to be the result of either foreign or domestic shocks. For example, for a *large* open economy, changes in domestic monetary and fiscal policies may affect import prices. Given our specification and the lack of data on the origins of shocks, we cannot distinguish between these different types of shocks. Regardless of the sources of these shocks, however, they will be captured by our import price equations.

In the Translog case, it is most convenient to derive the inverse demand equations in share form:

$$s_M = \beta_M + \phi_{MK} \ln x_K + \phi_{ML} \ln x_L + \phi_{ME} \ln x_E + \phi_{MM} \ln x_M + \phi_{MT} t - \alpha x_M \frac{\sigma_M^2 x_M + \sigma_{EM} x_E}{py} \quad (28)$$

$$s_E = \beta_E + \phi_{EK} \ln x_K + \phi_{EL} \ln x_L + \phi_{EE} \ln x_E + \phi_{EM} \ln x_M + \phi_{ET} t - \alpha x_E \frac{\sigma_E^2 x_E + \sigma_{EM} x_M}{py} \quad (29)$$

$$s_L = \beta_L + \phi_{LK} \ln x_K + \phi_{LL} \ln x_L + \phi_{LE} \ln x_E + \phi_{LM} \ln x_M + \phi_{LT} t \quad (30)$$

$$s_K = \beta_K + \phi_{KK} \ln x_K + \phi_{KL} \ln x_L + \phi_{KE} \ln x_E + \phi_{KM} \ln x_M + \phi_{KT} t, \quad (31)$$

where $s_i \equiv \overline{q}_i x_i/(py)$ $(i = M, E)$ and $s_j \equiv w_j x_j/(py)$ $(j = L, K)$ are the shares of imports, labor, and capital in total costs.

Given the estimates of the covariance matrix of q, derived from (25) and (26), the import share equations (28) and (29) can be rewritten in terms of the generated variables $\tilde{\overline{q}}_M, \tilde{\overline{q}}_E, \tilde{\sigma}_M^2, \tilde{\sigma}_E^2$ and $\tilde{\sigma}_{ME}$ as:

$$\tilde{s}_M = \beta_M + \phi_{MK} \ln x_K + \phi_{ML} \ln x_L + \phi_{ME} \ln x_E + \phi_{MM} \ln x_M + \phi_{MT} t - \alpha x_M \frac{\tilde{\sigma}_M^2 x_M + \tilde{\sigma}_{EM} x_E}{py} \quad (32)$$

$$\tilde{s}_E = \beta_E + \phi_{EK} \ln x_K + \phi_{EL} \ln x_L + \phi_{EE} \ln x_E + \phi_{EM} \ln x_M + \phi_{ET} t - \alpha x_E \frac{\tilde{\sigma}_E^2 x_E + \tilde{\sigma}_{EM} x_M}{py}, \quad (33)$$

where $\tilde{s}_M \equiv \tilde{\overline{q}}_M x_M/(py)$ and $\tilde{s}_E \equiv \tilde{\overline{q}}_E x_E/(py)$. The full model, therefore, consists of equations (30), (31), (32) and (33).

4.4 Stochastic Specification and Estimation Method

For empirical implementation the model has to be imbedded within a stochastic framework. To do this we assume that equations (30), (31), (32) and (33) are stochastic due to errors in optimization. We define the optimization errors in the share equations at time t as v_{Mt}, v_{Et}, v_{Lt} and v_{Kt}. We denote the column vector of disturbances at time t as $v_t \equiv (v_{Mt}, v_{Et}, v_{Lt}, v_{Kt})'$ and assume that the vector of disturbances is identically and independently, joint normally distributed with mean zero and non-singular covariance matrix Ω:

$$E(v_t v_s) = \begin{cases} \Omega & \forall\, s, t \text{ if } s = t \\ 0 & \text{if } s \neq t \end{cases}, \quad (34)$$

where Ω is a 4×4 positive definite matrix.

It is important to note that, usually, when estimating share equations, the equations are linearly dependent since shares sum to one. Consequently the optimization errors sum to zero, which means that the covariance matrix is singular. Since our data is constructed subject to the accounting constraint $q_M x_M + q_E x_E + w_L x_L + w_K x_K = py$, it may appear, at first, that a similar situation occurs in our application. The sum of the shares on the left hand side of (30)–(33) is $(w_L x_L + w_K x_K + \tilde{\bar{q}}_M x_M + \tilde{\bar{q}}_E x_E)/(py) = (w_L x_L + w_K x_K + q_M x_M + q_E x_E - u_M x_M - u_E x_E)/(py) = 1 - (u_M x_M - u_E x_E)/(py)$ where $u_i \equiv q_i - \tilde{\bar{q}}_i$ are the two import price forecast errors. Thus, summing equations (30)–(33), we get: $1 - (u_M x_M + u_E x_E)/(py) = \sum \lambda_h - \alpha(\sigma_M^2 x_M^2 + 2\sigma_{ME} x_M x_E + \sigma_E^2 x_E^2)/(py) + \sum v_h$ $(h = M, E, L, K)$, where $\lambda_h \equiv \partial \ln f(.)/\partial \ln x_h$. Note that $\sum \lambda_h = 1$ under constant returns to scale. Solving for the sum of optimization errors we therefore have $\sum v_h = [\alpha(\sigma_M^2 x_M^2 + 2\sigma_{ME} x_M x_E + \sigma_E^2 x_E^2) - u_M x_M - u_E x_E]/(py)$. Thus, for arbitrary values of u_M and u_E, the errors do not sum to zero and it is not necessary to drop one of the share equations.

While the production-function model treats input quantities, conceptually, as given, this is unlikely to be correct in a statistical sense, since employment, capacity, and import quantities are likely to depend on supply conditions as well. Again, to correct for possible simultaneous equations biases, we estimate the model using an iterative three-stage least squares (I3SLS) estimation method.[23].

5 Empirical Results

We first estimated the system of share equations using the observed — rather than the expected — price of imports.[24] Initial estimates indicated that the required concavity conditions were violated for some early observations. We, therefore, imposed concavity in 1954, using the technique of Wiley, Schmidt, and Bramble (1973). This turned out to be sufficient for the resulting estimates to satisfy all regularity conditions for all observations. Parameter estimates are given in the first column of Table 1. Asymptotic t-values are shown in parentheses.

Next, we estimated equations (30)–(33) using the expected import prices, but constraining α to zero. The estimates are shown in column 2 of Table 1. We also estimated equations (30)–(33), again using the expected import prices, but this time without constraining α. The

[23]Using the instruments listed in footnote 19.

[24]In this case, the shares add up to one, and one equation had to be omitted for estimation purposes; however, the estimation results do not depend on which equation is left out. The model is estimated from 1954 onwards since two observations are lost in the estimation of the ARCH model.

resulting parameter estimates are reported in the last column of Table 1. We verified that the required regularity conditions were met for all observations.

It is noteworthy that the estimate of α is significantly greater than zero. Thus, the evidence is consistent with the existence of risk aversion. The point estimate of α is, however, very small which suggests that uncertainty does not play a large role in production decisions. This impression is confirmed if we compare the point estimates shown in column 3 with those in columns 1 and 2.

Table 2 reports 1987 estimates of the Hicksian elasticities of complementarity (ψ_{hk}) for the three sets of parameter estimates contained in Table 1. These do not vary much between the three versions of the model. Thus, it appears that ignoring import price uncertainty does not have much impact on the results. Looking at the actual estimates, we find that oil and non-oil imports are Hicksian q-substitutes for each other. There is also evidence of a substitution relationship between imports of petroleum products and capital.[25] On the other hand, labor is a strong Hicksian q-complement for both types of imports and for capital.

Table 3 reports price and quantity elasticities estimates for selected years, using the unrestricted parameter estimates.[26] These are valid for the GNP function setting. They were defined in (13) and are computed using (15). The own price elasticities of the demand for both types of imports (defined for a given price of output and given factor endowments) are both larger than one in absolute value, although they are both declining through time. The Rybczynski elasticities indicate that an increase in the endowment of labor has a large positive impact on the demand for both types of imports, particularly imports of petroleum products. An increase in the endowment of capital, on the other hand, increases the demand for non-oil imports only by a small amount, and it actually decreases the demand for imports of petroleum products. Intuitively, this reflects the Hicksian substitution relationship between capital services and oil imports that we noted earlier. Consequently, as shown by the Stolper-Samuelson elasticities, an increase in either import price has little impact on the return to capital: it mostly hurts labor.

Tables 4 and 5 show yearly estimates of the elasticities of both types of import demand, output supply, and factor rewards with respect to non-oil and oil import price uncertainty,

[25]This result is not directly comparable to the finding of Berndt and Wood (1975) that capital and energy are Allen-Uzawa complements, since the Allen-Uzawa elasticities are defined for given input prices (cost funciton framework) whereas the Hicksian elasticities of complementarity are defined for given input quantities (production function setting). The passage from one set of elasticities to the other is not trivial and requires inversion of a bordered Hessian matrix; see Kohli (1991). Moreover, Berndt and Wood (1975) restrict their attention to the manufacturing sector and consider all forms of energy, much of which is of domestic origin.

[26]Figures for 1954 are not reported here: they are meaningless since the bordered Hessian of the production function is almost singular given that concavity was imposed at that observation.

respectively (ϑ_{hi}) as defined in (18). It is apparent that an increase in $\theta_i (i = M, E)$ has a very small impact on output, imports and factor payments. Nonetheless, several points should be made. First, while these point elasticities are small, they can yield relatively large effects, given that the estimates of θ_i fluctuate considerably over time. Second, the elasticities themselves are highly volatile through time. In particular, uncertainty seems to have played an important role starting in the mid-sixties and was especially large in the mid-seventies and early eighties. This is precisely when the θ_i's were largest[27] and it coincides with a period when the United States was subjected to several large foreign shocks, including the collapse of the fixed exchange rates regime and the two OPEC shocks. Third, it appears that oil import price uncertainty plays a relatively larger role than non-oil import price uncertainty (compare the estimates shown in Table 4 with those reported in Table 5), although the GNP share of imports of petroleum products is much smaller than that of non-oil imports. Fourth, it seems that import price uncertainty mostly hurts labor. Remember that the distributional effects depend on the signs of ε_{Li} and ε_{Ki}, $i = M, E$. As indicated in Table 3, ε_{LM} and ε_{LE} are both negative, while ε_{KM} and ε_{KE} are close to zero, the latter even being positive. Thus, not only does import price uncertainty lead to a reduction in national welfare (by increasing the 'shadow price of imports'), it also penalizes labor and may actually favor capital. It is also interesting to note that uncertainty in either import price tends to increase the demand for the other type of import. This follows from the substitutability relationship between oil and non-oil imports which was evidenced in Table 3.

The elasticities shown in Tables 4 and 5 are *point* estimates and also *partial* estimates. That is, they are only valid for small changes in uncertainty and they indicate the impact of a change in one type of uncertainty, holding the other type constant. In order to assess the *total* impact of import price uncertainty, we have simulated the model setting σ_M^2, σ_E^2, and σ_{ME} to zero. The results are reported in Table 6 as percentage changes from the control solution. As expected, a removal of uncertainty would have a positive effect on the supply of output and, generally, on the demand for imports. Wages would increase as well, while the effect on the return to capital is ambiguous due to the opposite signs of ε_{KM} and ε_{KE}. However, while the return to capital might fall in some periods and increase in others, it is only slightly affected by a removal of import price uncertainty. A somewhat unexpected result concerns the demand for imports. Specifically, a reduction in import price uncertainty need not lead to an increase in *both* types of imports. Thus, in 1987, a removal of import price uncertainty would have heavily favored the demand for imports of petroleum products. At the same time,

[27] δ_M peaks at 3.8% in 1981, and δ_E reaches 20.0% that same year.

due to the Hicksian q-substitutability between both types of imports, the demand for non-oil imports would, actually, have fallen somewhat.

The effects shown in Table 6 are calculated for a given price of output, given expected prices of imports and given factor endowments. The percentage changes in factor prices can, therefore, also be interpreted as relative changes in total factor payments. It is noticeable that the impact of uncertainty on the volume of non-oil imports is rather small: it is less than one tenth of one percent for nearly half the observations and it is less than one percent for all but three years. The impact was largest in 1981 when imports would have been higher by about 3.2 percent had it not been for uncertainty. Uncertainty seems to play a larger role for imports of petroleum products. Here, the impact exceeds one percent in nearly half the observations. By 1981, oil imports would have been larger by about 23.9 percent were it not for uncertainty.[28] This would have been translated to a 0.6 percent increase in output and a 1.2 percent increase in labor income. Finally, it is interesting to note that import price uncertainty seems to have started to play a relatively important role as early as 1965, i.e., about eight years before the collapse of the Bretton-Woods system.

Before we conclude, it is worth noting that the effects of uncertainty on input demand can also be modeled by introducing productivity shocks, in addition to uncertain input prices, directly into the model[29]. For example, suppose that there exist productivity shocks that affect the US production function, multiplicatively. Let these shocks be denoted by γ. The first-order conditions (3) and (4) are then given by:

$$pE(\gamma)f_i(x_M, x_E, x_L, x_K, t) = \overline{q}_i + \theta_i - \psi, \qquad i = M, E \tag{35}$$

$$pE(\gamma)f_j(x_M, x_E, x_L, x_K, t) = w_j - \psi, \qquad j = L, K, \tag{36}$$

where $\psi \equiv Cov[U'(\pi), \gamma]/E[U'(\pi)]$.

This framework would be consistent with a model in which price uncertainty is generated by productivity shocks and would enable us to estimate the effects of these shocks explicitly. As equations (35) and (36) indicate, such a framework could also be used to analyze the

[28]This is two years after the second oil shock, where the ARCH model estimates uncertainty to be at its peak. Of course, 1981 also coincides with a very severe downturn of the U.S. economy. However, since the comparison here is between the cases with and without uncertainty (i.e., what is usually referred to as the impact effect of uncertainty), the percentage changes reported in this table reflect the introduction of uncertainty and cannot be *directly* attributed to the recession. As was noted in footnote 22, however, since the US is a large economy, it is possible that the high level of uncertainty in this period, is itself a reflection of greater uncertainty associated with US productivity shocks. It should also be noted that the impact of the recession on the utilization of labor is taken into account, since the GNP function framework treats actual employment as given.

[29]We thank one of the referees for this suggestion.

effects of the correlation between import prices and productivity shocks on factor demand and imports. We hope to study such a model in future research.

6 Conclusions

The purpose of this paper was to examine the role of uncertainty in import decisions and to examine its effects on income distribution. This has enabled us to expand the production theory and GNP function approaches to import determination into a new direction. Our main results indicate that omitting import price uncertainty does not do much violence to the data. Furthermore, it appears that import price uncertainty has not been a major deterrent to international trade, except perhaps in the mid 1970s and early 1980s. In 1981, in particular, the resulting GNP loss may have amounted to as much as 17 billion dollars. Finally, whereas import price uncertainty mostly hurts labor, due to Hicksian substitution between oil imports and capital, capital owners may actually benefit from the higher shadow price of imports that results from uncertainty.

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Table 1: Parameter Estimates (t-values in parentheses)

	q_i $\alpha = 0$	$\overline{q}_i$ $\alpha = 0$	$\overline{q}_i$ $\alpha \neq 0$
β_M	0.04046	0.03945	0.03936
	(16.58)	(20.01)	(19.83)
β_E	0.00125	0.00254	0.00229
	(0.85)	(2.82)	(2.43)
β_L	0.52910	0.52584	0.52693
	(155.43)	(167.44)	(166.51)
ϕ_{MM}	-0.01389	0.00135	0.00153
	(-0.85)	(0.10)	(0.12)
ϕ_{ME}	-0.00594	-0.00317	-0.00307
	(-1.65)	(-1.14)	(-1.09)
ϕ_{ML}	0.05274	0.03020	0.02453
	(2.33)	(1.58)	(1.25)
ϕ_{EE}	0.00058	0.00195	0.00178
	(0.38)	(2.15)	(1.89)
ϕ_{EL}	0.00958	0.01338	0.01200
	(1.77)	(2.76)	(2.45)
ϕ_{LL}	-0.16279	-0.16093	-0.15298
	(-2.86)	(-3.32)	(-3.07)
ϕ_{MT}	0.00339	0.00245	0.00233
	(4.11)	(3.58)	(3.39)
ϕ_{ET}	0.00089	0.00074	0.00078
	(3.82)	(4.18)	(4.23)
ϕ_{LT}	-0.00545	-0.00482	-0.00450
	(-3.46)	(-3.56)	(-3.25)
α	—	—	0.00383
			(1.85)

Table 2: Hicksian Elasticities of Complementarity (1987 Estimates)

	q_i $\alpha = 0$	$\overline{q}_i$ $\alpha = 0$	$\overline{q}_i$ $\alpha \neq 0$
ψ_{MM}	-10.59697	-8.91411	-8.91543
ψ_{ME}	-2.15664	-0.82982	-0.62774
ψ_{ML}	2.03631	1.59073	1.48159
ψ_{MK}	0.08423	0.22805	0.37203
ψ_{EE}	-49.73148	-49.98365	-46.65620
ψ_{EL}	1.96895	2.49550	2.22954
ψ_{EK}	0.39514	-0.89069	-0.52594
ψ_{LL}	-1.54209	-1.55634	-1.53056
ψ_{LK}	1.53179	1.61846	1.61568
ψ_{KK}	-2.21208	-2.27050	-2.32128

Note: These estimates are based on the parameter values shown in Table 1.

Table 3: Price and Quantity Elasticities of Output Supply and Inverse Input Demands (GNP Function Setting)

	1955	1960	1970	1980	1987
i) Price elasticities of import demand/output supply					
ε_{YY}	0.04503	0.05490	0.07956	0.10762	0.13070
ε_{YM}	-0.04476	-0.05149	-0.06982	-0.09088	-0.11076
ε_{YE}	-0.00027	-0.00341	-0.00974	-0.01674	-0.01994
ε_{MY}	1.07873	1.04625	1.06099	1.09026	1.11544
ε_{MM}	-1.27654	-1.14722	-1.10997	-1.11622	-1.13066
ε_{ME}	0.19781	0.10097	0.04899	0.02597	0.01521
ε_{EY}	0.08247	0.65957	0.92583	1.01373	1.04838
ε_{EM}	2.49192	0.96084	0.30655	0.13109	0.07941
ε_{EE}	-2.57439	-1.62041	-1.23238	-1.14482	-1.12778
ii) Quantity elasticities of inverse factor demands					
ε_{LL}	-0.50532	-0.57176	-0.59101	-0.60263	-0.60917
ε_{LK}	0.50532	0.57176	0.59101	0.60263	0.60917
ε_{KL}	0.61714	0.73068	0.80810	0.83580	0.84766
ε_{KK}	-0.61714	-0.73068	-0.80810	-0.83580	-0.84766
iii) Rybczynski elasticities					
ε_{YL}	0.57629	0.59320	0.61308	0.61822	0.62000
ε_{YK}	0.42371	0.40680	0.38692	0.38178	0.38000
ε_{ML}	0.60067	0.89263	0.92393	0.87985	0.84197
ε_{MK}	0.39933	0.10737	0.07607	0.12015	0.15803
ε_{EL}	7.94898	3.63061	1.78589	1.32358	1.22957
ε_{EK}	-6.94898	-2.63061	-0.78589	-0.32358	-0.22957
iv) Stolper-Samuelson elasticities					
ε_{LY}	1.09730	1.11820	1.14917	1.18202	1.20857
ε_{LM}	-0.04745	-0.08281	-0.11397	-0.14023	-0.16297
ε_{LE}	-0.04985	-0.03539	-0.03520	-0.04178	-0.04559
ε_{KY}	0.98531	0.97996	0.99165	1.01239	1.03072
ε_{KM}	-0.03853	-0.01273	-0.01283	-0.02656	-0.04256
ε_{KE}	0.05322	0.03277	0.02118	0.01417	0.01185

Note: These estimates are defined for given import and output prices, and given factor endowments. They are based on the parameter values shown in Table 1, column 3.

Table 4: Elasticities with respect to Non-Oil Import Price Uncertainty

	$\vartheta_{YM} \times 10^2$	$\vartheta_{MM} \times 10^2$	$\vartheta_{EM} \times 10^2$	$\vartheta_{LM} \times 10^2$	$\vartheta_{KM} \times 10^2$
1954	-0.00067	-0.02607	0.15394	0.00162	-0.00310
1955	-0.00213	-0.06086	0.11880	-0.00226	-0.00184
1956	-0.00109	-0.02896	0.03814	-0.00157	-0.00049
1957	-0.00084	-0.02168	0.02156	-0.00135	-0.00020
1958	-0.00107	-0.02757	0.03105	-0.00163	-0.00033
1959	-0.00505	-0.11830	0.11652	-0.00787	-0.00150
1960	-0.00149	-0.03320	0.02780	-0.00240	-0.00037
1961	-0.00097	-0.02070	0.01673	-0.00155	-0.00025
1962	-0.00755	-0.15275	0.10287	-0.01231	-0.00171
1963	-0.00563	-0.11132	0.05502	-0.00954	-0.00081
1964	-0.00292	-0.05426	0.02706	-0.00484	-0.00059
1965	-0.00724	-0.12899	0.05531	-0.01205	-0.00148
1966	-0.01341	-0.22815	0.09003	-0.02212	-0.00300
1967	-0.01537	-0.26186	0.08630	-0.02562	-0.00272
1968	-0.04063	-0.67284	0.20940	-0.06709	-0.00739
1969	-0.05424	-0.87090	0.24332	-0.08920	-0.01033
1970	-0.05794	-0.92113	0.25440	-0.09458	-0.01065
1971	-0.04533	-0.70916	0.18607	-0.07354	-0.00814
1972	-0.07155	-1.08454	0.25110	-0.11550	-0.01344
1973	-0.08909	-1.31441	0.25376	-0.14368	-0.01703
1974	-0.02807	-0.40656	0.07594	-0.04499	-0.00558
1975	-0.05824	-0.84156	0.15292	-0.09314	-0.01112
1976	-0.01968	-0.27447	0.04495	-0.03118	-0.00407
1977	-0.05979	-0.80656	0.11533	-0.09419	-0.01343
1978	-0.00228	-0.02941	0.00383	-0.00355	-0.00059
1979	-0.02063	-0.25870	0.03038	-0.03204	-0.00574
1980	-0.03594	-0.44139	0.05184	-0.05545	-0.01050
1981	-0.35665	-4.25323	0.48332	-0.54579	-0.11080
1982	-0.18102	-2.12024	0.24347	-0.27496	-0.05758
1983	-0.04953	-0.56296	0.06080	-0.07462	-0.01650
1984	-0.00439	-0.04781	0.00454	-0.00656	-0.00157
1985	-0.00382	-0.04057	0.00357	-0.00568	-0.00143
1986	-0.02480	-0.25964	0.02058	-0.03667	-0.00921
1987	-0.01317	-0.13444	0.00944	-0.01938	-0.00506

Table 5: Elasticities with respect to Oil Import Price Uncertainty

	$\vartheta_{YE} \times 10^2$	$\vartheta_{ME} \times 10^2$	$\vartheta_{EE} \times 10^2$	$\vartheta_{LE} \times 10^2$	$\vartheta_{KE} \times 10^2$
1954	0.00008	0.00673	-0.08184	-0.00147	0.00175
1955	-0.00001	0.00477	-0.06211	-0.00120	0.00128
1956	-0.00002	0.00144	-0.01967	-0.00040	0.00040
1957	-0.00006	0.00279	-0.03872	-0.00080	0.00077
1958	0.00000	0.00028	-0.00392	-0.00008	0.00008
1959	-0.00087	0.03563	-0.54360	-0.01146	0.01118
1960	0.00001	-0.00020	0.00314	0.00007	-0.00006
1961	-0.00003	0.00069	-0.01150	-0.00025	0.00023
1962	-0.00005	0.00089	-0.01574	-0.00036	0.00031
1963	-0.00008	0.00098	-0.01817	-0.00045	0.00034
1964	-0.00027	0.00319	-0.06286	-0.00156	0.00118
1965	-0.00166	0.01569	-0.32827	-0.00849	0.00599
1966	-0.00375	0.03062	-0.67825	-0.01801	0.01218
1967	-0.00764	0.05033	-1.14037	-0.03131	0.01979
1968	-0.01865	0.11189	-2.63699	-0.07328	0.04581
1969	-0.02863	0.14733	-3.65798	-0.10496	0.06152
1970	-0.03568	0.17950	-4.51596	-0.12899	0.07761
1971	-0.03576	0.16716	-4.32349	-0.12462	0.07451
1972	-0.05115	0.20167	-5.54719	-0.16594	0.09180
1973	-0.08724	0.27423	-8.12917	-0.25700	0.12420
1974	-0.04117	0.12268	-3.75036	-0.11956	0.05716
1975	-0.08467	0.24429	-7.54536	-0.24154	0.11522
1976	-0.00214	0.00534	-0.17750	-0.00586	0.00262
1977	-0.00790	0.01649	-0.59728	-0.02054	0.00821
1978	-0.00055	0.00100	-0.03958	-0.00140	0.00051
1979	-0.00044	0.00070	-0.02993	-0.00109	0.00036
1980	-0.03877	0.06014	-2.65149	-0.09678	0.03281
1981	-0.33806	0.49272	-22.92122	-0.84274	0.28310
1982	-0.20044	0.29046	-13.78641	-0.50333	0.17644
1983	-0.06893	0.09104	-4.62616	-0.17109	0.05852
1984	-0.02023	0.02243	-1.28484	-0.04903	0.01525
1985	-0.02817	0.02813	-1.74061	-0.06753	0.02000
1986	-0.00973	0.00861	-0.57419	-0.02267	0.00641
1987	-0.16602	0.12664	-9.38840	-0.37955	0.09861

Table 6: Impact of Import Price Uncertainty (in percentages)

	gross output	non-oil imports	oil imports	wages	profits
1954	0.00043	0.00979	0.01585	0.00123	-0.00051
1955	0.00161	0.04311	0.00310	0.00366	-0.00081
1956	0.00085	0.02193	0.00130	0.00188	-0.00039
1957	0.00087	0.01731	0.02576	0.00222	-0.00077
1958	0.00084	0.01928	0.00879	0.00190	-0.00048
1959	0.00771	0.09789	0.45792	0.02215	-0.00997
1960	0.00127	0.02833	0.00018	0.00255	-0.00035
1961	0.00091	0.01921	0.00281	0.00184	-0.00027
1962	0.00663	0.14356	-0.04107	0.01219	-0.00055
1963	0.00564	0.11561	-0.02239	0.01036	-0.00046
1964	0.00354	0.05799	0.05003	0.00727	-0.00117
1965	0.01174	0.14484	0.35950	0.02634	-0.00636
1966	0.02319	0.25623	0.76932	0.05208	-0.01238
1967	0.03156	0.27489	1.38345	0.07485	-0.02188
1968	0.07386	0.67109	2.92683	0.16904	-0.04443
1969	0.10768	0.90613	4.35447	0.24455	-0.06290
1970	0.12222	0.92862	5.47607	0.28268	-0.08203
1971	0.10238	0.65119	5.11704	0.24236	-0.07720
1972	0.13790	0.95769	5.97098	0.31091	-0.08239
1973	0.18473	1.05430	8.55974	0.41781	-0.10870
1974	0.07462	0.29899	4.02585	0.17656	-0.05520
1975	0.11208	0.47420	6.40699	0.27258	-0.09312
1976	0.02011	0.24552	0.11772	0.03409	0.00194
1977	0.06422	0.74446	0.44440	0.10870	0.00662
1978	0.00266	0.02750	0.02868	0.00460	0.00019
1979	0.02222	0.28179	-0.06496	0.03396	0.00702
1980	0.07002	0.36267	2.52847	0.14425	-0.02314
1981	0.61388	3.20845	23.87692	1.26301	-0.18719
1982	0.37306	1.76133	14.90313	0.77469	-0.13541
1983	0.12665	0.49953	5.05150	0.26308	-0.04704
1984	0.03112	0.02349	1.62003	0.06948	-0.01662
1985	0.04829	-0.01397	2.70184	0.10955	-0.02797
1986	0.03789	0.19780	0.99584	0.07021	-0.00342
1987	0.28100	-0.23106	16.08380	0.61981	-0.13832

Explanations: These estimates show the impact on output, imports, and factor payments of a reduction in uncertainty, modeled by setting σ_M^2, σ_E^2, and σ_{ME} to zero.