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THE PRICE EFFECTS OF EXCHANGE RATE CHANGES: MODELS, EMPIRICAL EVIDENCE, AND NOTES ON AGGREGATION BIAS

by

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THE PRICE EFFECTS OF EXCHANGE RATE CHANGES: MODELS, EMPIRICAL EVIDENCE, AND NOTES ON AGGREGATION BIAS*/

1. Introduction

The recent concurrence of rapid domestic price increases with large par value adjustments and volatile floating rates has rekindled an interest in the international transmission of inflation. In particular, there has been a call to remodel the process of domestic inflation in a manner which highlights "the internationally traded goods, whose prices (adjusted for trade barriers) must be everywhere the same."1/

The theoretical focus of this paper is on those homogeneous tradeable goods which are supplied to world markets under approximately competitive conditions. Included among these goods are most tradeable primary goods --- foodstuffs and other basic industrial commodities, excluding some, such as crude petroleum, which are not competitively priced --- and many intermediate goods, such as homogeneous steel items and textile yarns and fabrics. Also included are any finished goods that might be viewed, following Lancaster (1966), as bundles of homogeneous competitively-priced characteristics.2/ Each of these goods is viewed as having a uniform competitively-determined dollar price throughout the world (thus ignoring transport costs and trade barriers), and the analysis focuses on the extent to which this price is affected by exchange rate changes, with limited attention also to the price effects of monetary policies and other factors. If we understood the determinants

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*/ This paper has benefitted from comments by Norman Fieleke, Duncan Ripley, and several others. Conclusions and opinions should not be associated with the Federal Reserve Board or anyone else on its staff.

1/ Caves (1973, p.1)

2/ Such a view of finished goods has been applied by Kravis and Lipsey (1971, Chapter 5).

of the world prices of these goods we would understand sizeable components of our domestic price indexes.

Section 2 develops a familiar elasticities relationship between the rate of price change for a homogeneous, competitively-priced good and the rates of change of exchange rates and the other arguments of demand and supply functions. The framework is one of partial equilibrium, with markets fairly isolated by commodity. Several interesting conclusions emerge however, and some crude quantitative estimates are offered as lower bounds on the short-run effects of dollar devaluations on domestic price indexes. An examination of the model in a quantity theory context suggests a possibly-meaningful aggregation of the rates of growth of money supplies in different countries. At the end of this section, feedbacks between prices and wages are examined.

Section 3 turns to a general equilibrium framework as a more general means of isolating the factors responsible for the real effects of exchange rate changes. Without some combination of money illusion, sticky prices, imperfect foresight and adjustment lags, exchange rate changes would have no real effects in a competitive world economy, and despite possible differences in price-level effects, the choice between fixed and flexible-rate regimes would be irrelevant to economic welfare.

Section 4 returns to the partial equilibrium framework of Section 2 and examines the relative movements of dollar prices in the United States and Germany for 11 different industries during the 1968-73 period. The data show substantial movements in ratios of the two countries' dollar price indexes at this level of aggregation. It is argued that a significant part of this movement may be due to the use of different subindustry weights in constructing the U.S. and German industry price indexes. Section 5 examines some implications for those econometric models which regress domestic price aggregates on import price indexes.

2. A Partial-Equilibrium Model of World Prices

This section develops a familiar model of the world price of a homogeneous good which is demanded and supplied by competitive groups with no market power. For such a good, demand and supply functions are well-defined, and (neglecting changes in inventories and order backlogs) the world market may be assumed to be continuously cleared via price adjustment.

The market-clearing condition may be written as

$$\sum_i D_i(k_i p, x_{i1}, \ldots, x_{in}) = \sum_i S_i(k_i p, z_{i1}, \ldots, z_{im}) \tag{2.1}$$

where D_i and S_i are the quantities demanded and supplied by country i, p is the dollar price of the good, k_i is the currency-i price of one dollar, and the x_{ij} and z_{ij} arguments of the demand and supply functions include other policy variables, income or wealth variables, capacity and production cost variables, and whatever else is relevant. Total differentiation of this expression and manipulation then yields an expression for the proportionate change in market clearing price ($\hat{p}$) that follows any set of proportionate changes in exchange rates ($\hat{k}_i$) and other variables ($\hat{x}_{ij}$ and $\hat{z}_{ij}$). Specifically,

$$\hat{p} = \frac{-\sum_i(\eta_i d_i + \epsilon_i s_i)\,\hat{k}_i + \sum_i\sum_j\left(\theta_{ij} d_i \hat{x}_{ij} - \zeta_{ij} s_i \hat{z}_{ij}\right)}{\sum_i(\eta_i d_i + \epsilon_i s_i)} \tag{2.2}$$

(2.2)

where $d_i = \frac{D_i}{\sum_i D_i}$ is the share of country i in world consumption (or absorption)

$s_i = \frac{S_i}{\sum_i S_i}$ is the share of country i in world production

$\eta_i = - \frac{k_i p}{D_i} \frac{\partial D_i}{\partial(k_i p)}$ is the price elasticity of demand in country i, defined to be normally positive

$\epsilon_i = \frac{k_i p}{S_i} \frac{\partial S_i}{\partial(k_i p)}$ is the price elasticity of supply in country i

θ_{ij} is the elasticity of D_i with respect to x_{ij}

ζ_{ij} is the elasticity of S_i with respect to z_{ij}

To the extent that cross-price terms are typically ignored, (2.2) is typically applied within a partial equilibrium framework.

Equation (2.2) provides a complete explanation of changes in price when the underlying demand are supply relationships are fully specified.[3/] The parameters of (2.2) also describe the net exports of

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3/ Ridler and Yandle (1972) have derived a variation on condition (2.2), based on the price elasticities of world demand for <u>imports</u> and world supply of <u>exports</u>, rather than on price elasticities of total demands and supplies in different countries. Their variation can be applied to data on import and export shares, rather than consumption and production shares; but it is doubtful that their elasticity parameters are anywhere near as stable as those in condition (2.2), and this calls into question the usefulness of their approach. Note specifically that for most commodities, imports or exports will be zero in some countries, in which case the associated elasticities are infinite. Moreover, for the world as a whole, elasticities of export supply and import demand will decline in absolute values as world trade volume grows relative to world production and consumption.

the good in question by country i: $S_i - D_i$. Conventional import and export equations are inappropriate at this extreme level of disaggregation.

EMB (Ltd.) Research Economists (1973) have used equation (2.2) to derive a formula for estimating the <u>ceteris paribus</u> effects of <u>isolated</u> exchange rate changes on prices.[4/]

$$(\hat{p})_{\substack{ceteris\\paribus}} = - \frac{\Sigma(\eta_i d_i + \varepsilon_i s_i)\hat{k}_i}{\Sigma(\eta_i d_i + \varepsilon_i s_i)} \qquad (2.3)$$

EMB assume (a) a short-run context in which supply elasticities are zero (ϵ_i = o for all i); and it is also assumed that (b) demand elasticities are identical in all countries ($\eta_i = \eta$ for all i). Since $\Sigma d_i = 1$, this implies

$$(\hat{p})_{\substack{ceteris\\paribus}} = - \Sigma_i d_i \hat{k}_i \qquad (2.4)$$

The d_i can be measured directly from national consumption data if available, or assumptions about consumption shares can be made on the basis of national income levels.[5/] For medium-run analysis it is preferable to replace assumption (a) with the alternative simplifying assumption that (c) supply elasticities are identical in all countries ($\epsilon_i = \epsilon$ for all i).

4/ Clark (1974) has used a similar formula derived from the Ridler and Yandle (1972) variation of (2.2).

5/ Between December 1972 and June of 1973, the BLS dollar price index for foodstuffs increased by 32.8 percent, and there was a 26.2 percent increase in the price index for nonfood industrial raw materials. Using equation (2.4), EMB have estimated that from January through July of 1973, roughly one-sixth of the rise in the dollar prices of foodstuffs and one-third of the rise in the dollar prices of nonfood industrial raw materials could be attributed to the depreciation of the dollar.

This replaces (2.4) with

$$(\hat{p})_{\substack{cet.\\par.}} = \frac{-\sum_i (\eta d_i + \epsilon s_i)\hat{k}_i}{\eta + \epsilon} \qquad (2.5)$$

A hypothetical application leads to some interesting qualitative and quantitative conclusions. Suppose the dollar and the other North and South American currencies depreciate as a unit against the currencies of the rest of the world, with exchange rates fixed within both the Amercian (A) and rest of world (ROW) blocs. For any given tradeable good, under assumptions (a) and (b) and condition (2.4), each one percent depreciation raises the dollar price in the short-run by $d_{ROW} = 1 - d_A$ percent. Note:

(i) When a country or bloc devalues, the percentage change in its own-currency price of any homogeneous competitive tradeable good is not the full amount of the devaluation, but rather, in the short-run, the percentage devaluation multiplied by the share of the rest of the world in world consumption of the good.

(ii) Since the rest of the world consumes different shares of different tradeable goods, a devaluation changes the relative dollar prices of different tradeables.

(iii) In the short-run, for a given percentage devaluation, the percentage increase in the own-currency price of a tradeable will be smaller, the greater is the share of the devaluing country or bloc in world consumption (not trade) of the good.

In the medium run, under assumptions (b) and (c) and condition (2.5), each one percent depreciation raises the dollar price by $\frac{\eta d_{ROW} + \epsilon s_{ROW}}{\eta + \epsilon}$ percent, or by a weighted average of the consumption and production shares of the rest of the world. Thus

(iv) In the medium run, a given percentage devaluation will lead to a smaller percentage increase in the own-currency price of a tradeable, the greater are the shares of the devaluing country or bloc in world consumption and production (not trade) of the good.

And, for vague comparisons of a point of time in the short-run ($\eta > o$, $\epsilon = o$) with a point of time in the medium-run ($\eta > o$, $\epsilon > o$),

(v) The medium-run price will exceed the short-run price if and only if the devaluing country or bloc has a share in world consumption larger than its share in world production.

To these qualitative conclusions we can add the following very approximate quantitative estimates. Suppose, as a ballpark estimate, that the American bloc consumes 20 percent of the world's foodstuffs and nonfood basic raw materials;[6] and for convenience, assume that its production share is the same. Under these assumptions, an American devaluation increases the dollar prices of primary tradeables by roughly 80 percent of the devaluation on the average. Using the facts that the input/output coefficient for foodstuffs/processed foods is .286, and that foodstuffs and other primary tradeables have effective weights of roughly .1 in the CPI and .3 in the WPI,[7] the effects of a devaluation on prices of primary tradeables alone is seen to raise the

6/ Among such primary tradeable commodities there is considerable variance in the American consumption share, which is roughly 12.5% for wheat and wheat flour, 50% for feedgrains (corn, barley, oats, sorghum), 0% for rice, ...

7/ The prices of primary products are "double-counted" in the WPI, receiving sales weights as primary product prices and additional effective weights as the input prices that underlie the sales prices of intermediate and finished products.

costs of producing the food component of the CPI by roughly 23 (=80x.286) percent of the devaluation, the total CPI bundle by roughly 8 percent of the devaluation, and the WPI bundle by roughly 24 percent of the devaluation.[8/] Such impacts would occur in as short a period of time as domestic industries would take to shift forward the first round of their cost increases; and in the longer run, the inflationary effects would spiral. These estimates argue that devaluations are much more inflationary than is suggested by a simple ratio-of-imports-to-apparent-consumption approach (e.g., see Hasson (1973)), primarily because they allow for the fact that devaluations have major effects on the dollar prices of domestically-produced primary products, as well as on the dollar prices of imports.

It should be stressed that these numbers reflect a strictly cost-push view of the inflation of intermediate and finished goods prices. As such, they should be considered as lower bounds on the estimated effects of dollar depreciation on domestic price indexes. Those intermediate and finished-good components of the CPI and WPI which, like primary tradeables, can be viewed as homogenous competitively-marketed goods (or bundles of Lancaster-type characteristics) will show even larger dollar price increases, with a few exceptions perhaps for items whose world consumption is very strongly dominated by the American bloc.

Up to this point we have been considering the *ceteris paribus*

8/ For a more detailed explanation of these numbers see Isard (1974).

effects of isolated exchange rate changes on prices, ignoring any changes in policy parameters and other non-price variables which influence demands and supplies. In reality, exchange rate changes are likely to occur in response to differential rates of inflation, as generated by national policy stances and other factors, and may be accompanied by changes in other policy instruments. Thus, it is desirable to model the price effects of exchange rate changes in the broadest context possible. This requires that the demand and supply relationships be specified to explicitly incorporate important policy instruments and to appropriately reflect the channels through which changes in these instruments affect demands and supplies. While realistic modeling of the price effects of policy stances (both prior to and subsequent to exchange rate changes) is far beyond the scope of this paper, an abstract example may provide some additional insights into the determinants of world prices.

To provide a simple illustration which highlights the role of demand-management policy, consider a quantity-theory world with exogenous supplies. Focusing on a single homogeneous good, write

$$D_i = c_i (k_i p/w_i)^{-\eta_i} (Y_i/w_i)^{\theta_i} \tag{2.6}$$

and define

$$v_i = Y_i/M_i \tag{2.7}$$

where

w_i = currency-i price of an arbitrary numeraire good in country i[9/]

9/ Introduction of the numeraire price insures that demands are homogeneous of degree zero in prices and nominal incomes.

Y_i = nominal income in country i

M_i = nominal money supply in country i

v_i = velocity of money in country i

θ_i = income elasticity of demand in country i

Then substitute (2.7) into (2.6) and totally differentiate the market clearing condition

$$\sum_i c_i (k_i p/w_i)^{-\eta_i} (M_i v_i/w_i)^{\theta_i} = \sum_i S_i \qquad (2.8)$$

and maniputate to obtain

$$\hat{p} = \frac{-\sum_i d_i \eta_i \hat{k}_i + \sum_i d_i \theta_i (\hat{M}_i + \hat{v}_i) - \sum_i s_i \hat{S}_i + \sum_i d_i (\eta_i - \theta_i) \hat{w}_i}{\sum_i \eta_i d_i} \qquad (2.9)$$

where "^" above a variable indicates a proportionate rate of change. For the time being we shall view the $\hat{w}_i$ as independent of $\hat{p}$ and the other variables in (2.9), but this unrealistic assumption will later be relaxed.[10/]

Condition (2.9) will not be very interesting to someone who views aggregate demand as the sum of several final demand components and does not believe that this sum exhibits constant price and national income elasticities. Nor will it be interesting to someome who believes that

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10/ To the extent that $\hat{w}_i$ (which will later be viewed as the rate of change of the wage rate in country i) is linked to the rates of increase of other prices, exchange rate changes and monetary expansions touch off inflationary spirals, with long-run impacts which differ from the coefficients on k_i and $\hat{M}_i$ in (2.9). Note that when the real money supply is held constant in country i, i.e., when $\hat{M}_i = \hat{w}_i$, an increase in the numeraire price imparts an upward push to other prices. However, this impact on prices is dampened and possibly reversed when the nominal money supply is held constant in country i, i.e., when $\hat{M}_i = 0$, since an increase in the numeraire price (assuming $\hat{v}_i = 0$) then implies a decline in real income and demand.

velocities are unstable and unpredictable, so that (2.9) obscures the underpinnings of a potentially large portion of $\hat{p}$. Finally, the assumption of exogeneous supplies may be unacceptable. If we impose a time dimension on (2.9) by assuming that the price change occurs during a specific time interval following the changes in the right-hand-side variables, with demand elasticities appropriate to this interval, then the assumption of exogeneous supplies is an assumption that it takes longer than this time interval for supplies to be affected by changes in exchange rates, money supplies, velocities or prices. In some short-run contexts --- in particular, for crops with long growing seasons --- this assumption may be valid.

Condition (2.9) allows us to made crude comparisons of the rates of inflation that would occur in different hypothetical states of the world. If we can identify an initial state of the right-hand-side variables, then we can determine the price effects of any change in these variables from their initial state --- or from the values that they otherwise would have taken. In this sense we can examine the price effects of exchange rate changes with or without accompanying changes in other right-hand-side variables. It is easy to see that (2.9) includes (2.4) as the special case of a short-run context in which the exchange rate change is not accompanied by (or responsible for) changes in the rates of change of money supplies, velocities, commodity supplies or numeraire prices, and in which $\eta_i = \eta$ for all i.

Condition (2.9) also focuses on the price effects of the rates of growth of nominal money supplies. Within a <u>ceteris</u> <u>paribus</u> context:

(vi) The effect of the rate of growth of the money supply in country i on the price of any homogeneous, competitively-marketed good is positively related to the share of country-i in world consumption of that good.

If we ignore the important effects of money supply growth on velocities, exchange rates, production, and numeraire prices, condition (2.9) suggests that the effects of money supply growth on the price of good j may be summarized (after the addition of appropriate commodity subscripts) as:

$$\hat{p}_j = \frac{\sum_i d_{ij}\theta_{ij}\hat{M}_i}{\sum_i \eta_{ij} d_{ij}} \qquad (2.10)$$

Thus, if we are interested in the effects of money supply growth on a world price index

$$P = \sum_j q_j p_j \qquad (2.11)$$

and if we are willing to assume that all countries exhibit the same price and income elasticities of demand for each commodity ($\eta_{ij} = \eta_j$ and $\theta_{ij} = \theta_j$ for each j), we have

$$\hat{P} = \sum_j b_j \hat{p}_j = \sum_j \frac{b_j \theta_j}{\eta_j} \sum_i d_{ij}\hat{M}_i$$

where b_j is the base-period value share, $q_j p_j / \sum_j q_j p_j$. Hence,

$$\hat{P} = \sum_i \left(\sum_j \frac{b_j \theta_j d_{ij}}{\eta_j} \right) \hat{M}_i \qquad (2.12)$$

Condition (2.12) might be considered an appropriate summary of the world inflationary consequences of a given configuration of national monetary growth rates. Note that the weights in (2.12) are independent of the units in which national money supplies are denominated, unlike the weights in any meaningful measure of the level of the world money supply. Note again that weights reflect consumption shares.

It is now time to deal with the fact that numeraire price changes are linked to changes in the prices of other commodities. It is particularly convenient to chose leisure (or labor) as the arbitrary numeraire, with w_i representing the own-currency wage rate in country i. A simple hypothesis, then, is that changes in wage rates are linked to changes in the own-currency prices of final consumption goods

$$\hat{w}_i = \hat{w}_{io} + \sum_{j=1}^{J} a_{ij} \left(\hat{k}_i + \hat{p}_j\right) \qquad (2.13)$$

where the a_{ij} weights may be zero for items that do not enter final consumption baskets, where $\hat{w}_{io}$ is predetermined to reflect productivity growth, and where nontradeable consumption goods may be included among the set of J commodities.

The introduction of this price-index escalator[11/] for wages forces us to be more explicit about time lags. If wage escalation lags price increases, we might choose to view the $\hat{w}_i$ as predetermined and independent of $\hat{p}$ in condition (2.9). Condition (2.9) might still be

11/ Milton Friedman has recently proposed a strengthening of such escalator clauses. See Wall Street Journal, April 9, 1974 an adequate quantification of the short-run inflationary shock effects of exchange rate changes and money supply growth, but it tells us little about the dynamics of price and wage adjustment.

Alternatively, the wage adjustment hypothesized in (2.13) might be viewed as instantaneous (again obscuring the dynamics of price and wage adjustment). In this case we could write out condition (2.9) for each of the J commodities, imposing the definitional assumption that $d_{ij} = s_{ij} = 1$ for nontradeables of country i, and substituting condition (2.13) to get a set of J equations in J prices. (In using (2.9) for all commodities we are ignoring non-competitive markets.) Without spelling out the explicit solution, we may note that the reduced-form solution for $\hat{P}_j$ is a linear combination of the $d_{ij}\hat{k}_i$, $d_{ij}(\hat{M}_i+\hat{W}_i)$ and $s_{ij}\hat{S}_{ij}$ --- the right-hand-side terms of condition (2.9). Thus, we retain the conclusions that the own-currency price effects of exchange-rate changes and rates of money supply growth are positively related to consumption shares in the short-run, and hence are different for different commodities.

As an example, consider the case of two countries or regions (i=A,R) with two tradeable goods (j=1,2) and leisure, the numeraire good; and denominate world prices in the currency of region A, fixing $\hat{k}_A = 0$. As world consumption shares, assume $d_{A1} = .25$, $d_{R1} = .75$, $d_{A2} = d_{R2} = .5$; and for elasticities, assume $\theta_{A1} = \theta_{R1} = \theta_{A2} = \theta_{R2} = 1$, $\eta_{A1} = \eta_{R1} = .8$, and $\eta_{A2} = \eta_{R2} = 1.1$. Suppose, initially, that all prices and exchange rates are unity, that the world supply of each good is the same (e.g., 100 units), and that the escalators between rates of price increase and rates of wage increase are based on the initial period consumption weights of each region:

$$\hat{w}_i = \frac{d_{i1}}{d_{i1}+d_{i2}} \hat{p}_1 + \frac{d_{i2}}{d_{i1}+d_{i2}} \hat{p}_2 + \hat{k}_i = \begin{cases} \frac{1}{3} \hat{p}_1 + \frac{2}{3} \hat{p}_2 & \text{for } i = A \\ \frac{3}{5} \hat{p}_1 + \frac{2}{5} \hat{p}_2 + \hat{k}_R & \text{for } i = R \end{cases} \quad (2.14)$$

Under these assumptions, a straight forward (though lengthy) manipulation of condition (2.9) yields[12]

$$\hat{p}_1 = 1.098\,[.25(\hat{M}_A+\hat{v}_A)+.75(\hat{M}_R+\hat{v}_R-\hat{k}_R)] - .098[.5(\hat{M}_A+\hat{v}_A) + .5(\hat{M}_R+\hat{v}_R-\hat{k}_R)]$$

$$\hat{p}_2 = 0.049[.25(\hat{M}_A+\hat{v}_A) + .75\ (\hat{M}_R + \hat{v}_R - \hat{k}_R)] + .951\ [.5(\hat{M}_A+\hat{v}_A) + .5(\hat{M}_R+\hat{v}_R-\hat{k}_R)] \quad (2.15)$$

In each equation the square-bracketed term with the larger coefficient is dominated by the direct or first-round impacts of exchange-rate and money supply shocks on prices; while the term with the smaller coefficient, as well as a small part of the larger coefficient, reflects the additional indirect effects due to induced changes in the numeraire prices.[13] Thus, a devaluation of currency-A vis-a-vis currency-R (e.g., $\hat{k}_R = -.01$), *ceteris paribus*, increases the currency-A price of good 1 by 77.4 percent of the devaluation percentage, while the currency-A price of good 2 increases by 51.3 percent of the devaluation. In region A the numeraire price rises by 60.0 percent of the devaluation, and "real income" falls by the same percentage. From (2.6) we see that both the relative price effect and the real income effect operate to

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12/ This condition assumes no changes in supplies. For more generality, insert $\sum_{i,j} s_{ij} \hat{S}_{ij}$ within each square bracket.

13/ In this case the indirect effects are relatively small because the $(\eta_i - \theta_i)$ are small; see condition (2.9).

reduce real demand for good 1 in region A, while the income effect outweighs the relative price effect in also reducing the region-A demand for good 2. In addition, the devaluation reduces own-currency prices of tradeables and the numeraire in region R, where real demands increase for both goods. With fixed supplies in the short-run, real trade balances for both tradeables shift toward lower deficits (or higher surpluses) for region A, although in other examples this might not be the case.

3. The Neutrality of Devaluations Under Flexible Prices, Perfect Foresight, and Instantaneous Real Adjustments: An Abstract General Equilibrium Framework

The previous section has developed a model of price under implicit partial-equilibrium assumptions which isolate the market for each good from the markets for other goods. This section turns to a general equilibrium framework, too unwieldy to suggest estimable price equations, but yielding interesting conclusions nevertheless.[14]

Just as the previous section has taken real demands to be homogeneous of degree zero in prices and nominal income, so should it be assumed that in the long run, real supplies are independent of the absolute price level, and thus homogeneous of degree zero in the nominal values of explanatory variables. When we add the additional abstract assumptions that (a) prices are completely flexible and that demanders and suppliers (b) have perfect foresight, (c) are able to adjust their real demands and supplies instantaneously by the full optimal long-run

14/ This section draws heavily on Isard and Porter (1970).

responses to relative price changes, and (d) behave in a manner which satisfies certain convexity conditions, then it can be argued that exchange rate changes have no effects on real economic magnitudes. Under such conditions the nature of the exchange rate regime --- fixed or flexible --- has no real significance. This result is analagous to the theorem that inflation in a closed economy can be neutral under similar conditions.[15] Although the assumptions underlying the arguments describe an extremely unrealistic world, this abstract case extends our understanding of the reasons that exchange rate changes are not neutral in the real world.

The argument may be sketched as follows. Consider a competitive economy such as that described by Arrow and Debreu (1954). Essentially, each economic agent is a competitor who takes present and future prices as given and exhibits maximizing behavior under which his real demands and supplies satisfy various convexity conditions and are homogeneous functions of degree zero in nominal variables. Arrow and Debreu have shown that such an economy has a real multi-period competitive equilibrium --- not necessarily unique --- in which all economic agents are simultaneously maximizing their objective functions subject to budget constraints and a given consistent vector of equilibrium, market-clearing prices. By the homogeneity condition, any scalar multiple of an equilibrium price vector is also an equilibrium price vector. Under the extreme assumptions of (a) flexible prices, (b) perfect foresight

15/ See Phelps (1965).

of future prices and (c) ability to adjust real demands and supplies instantaneously, there is nothing to prevent the economy from reaching such an equilibrium.

In modeling this multi-period economy we may include debt in the commodity set, perhaps imposing an additional terminal-period constraint to insure that debts are eventually settled.16/ When agents are grouped by country or region, the individual budget constraints insure that values of regional excess demands for debt (capital account surpluses) balance the values of regional excess supplies of other commodities (trade balance deficits) in each period. Note that:

> (i) Changes in any country's trade balance over time will reflect its intertemporal consumption preferences relative to its production possibilities, in addition to any changes in the price, exchange rate and activity variables to which attention is usually restricted in econometric studies.17/

Now consider such a multiregional multiperiod economy in a position of initial equilibrium. Suppose there are n regions and in each period focus on the n-1 exchange rates for the currency unit of region 1 in terms of the currency units of regions 2, ..., n. Within the equilibrium price vector for this economy, the only constraint on the price subvector for region 2 in any period is that it must equal the product of the price subvector for region 1 and the appropriate

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16/ Like other commodities, debt has a market-clearing price which adjusts the excess demands of borrowers to the excess supplies of lenders in each period.

17/ To the extent that intertemporal consumption preferences and production possibilities change slowly this is an academic point.

exchange rate, adjusted for the cost of real transportation inputs.[18/] More specifically, for each time path of exchange rates of regions 2, ..., n, there exist time paths of price subvectors for these regions that are consistent with the same real world-wide equilibrium.[19/] Thus:

> (ii) In the absence of money illusion, price rigidities, imperfect foresight and adjustment lags, the economy is continuously in real equilibrium and there exists a real equilibrium time path which is independent of the extent and frequency of changes in the time paths of exchange rates. In such a world exchange rate changes may be neutral, and will be neutral if real equilibrium is unique. In the latter case the nature of the exchange rate regime -- fixed or flexible -- has no real economic significance, despite possible differences in price-level effects.

This conclusion only applies to an extremely abstract world. Its usefulness is that it emphasizes the conditions which must underlie the real effects of exchange rate changes, these being: (1) money illusion, or demands and supplies which are not homogeneous of degree zero in nominal variables; (2) sticky prices; (3) imperfect foresight; and (4) inability to adjust quickly to changes in optimal demand and supply positions. We may note several ways in which these factors interact to permit real impacts of exchange rate changes.

First, demanders and suppliers are often locked into long-term contracts and physical plant and equipment assets at the time of exchange

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18/ See Isard and Ostroff (1958) for an extension of the Arrow and Debreu (1954) theorem to a multiregional economy with transport costs.

19/ Note the suggestion that when a country's exchange rate is adjusted, the levels of all own-currency prices change in the opposite direction by the same proportion.

rate changes. Hence, they are often unable to adjust their real positions quickly, due largely to imperfect foresight at the time of contract or physical investment.

Second, due to imperfect foresight and lack of liquid debt instruments denominated in real terms, exchange rate changes often lead to significant wealth effects. Because of the desire for transactions balances, the illiquidity and high storage costs of physical assets, and the lack of liquid assets denominated in real terms, households and firms hold significant portions of their wealths in assets denominated in nominal terms. Forward exchange markets provide a means of hedging against exchange risk, but imperfect foresight, transactions costs, and the limited access of "speculators" to forward markets preclude an adequate mechanism for insuring the real value of nominally-denominated assets.

Third, some prices are sticky because products are differentiated and industries are oligopolistic, so that the competitive model does not strictly apply. In particular, prices will be sticky if price-setting oligopolists have healthy profit margins to begin with, lack complete information about industry demand functions and the reaction functions of other oligopolists, and find it costly to reassess pricing strategies and advertise new prices at frequent intervals.

Fourth, wages are sticky because suppliers of labor, lacking perfect information and facing search and relocation costs, find themselves locked into firms and geographic regions.

4. International Comparisons of Industry Price Movements

In this section we return to the partial-equilibrium framework of Section 2, in which markets are isolated by commodity but not by region. For empirical estimation of price equations, isolation by commodities (i.e., the neglect of cross-price effects) is extremely convenient; and in addition, it usually is desirable to group commodities into industry or end-use aggregates. However, when we compare dollar price indexes for similar tradeable-goods industries in different countries, concentrating in this section on the United States and Germany, we find substantial divergence over time.[20] We shall first present evidence of this divergence and then attempt to reconcile this evidence with the view that tradeable-goods industries are to a large extent aggregates of homogeneous, competitively-marketed items with similar dollar prices throughout the world.

The data selected for comparison are monthly indexes of German export prices and U.S. wholesale prices, from January 1968 through October 1973, for 11 different industries: apparel; industrial chemicals; drugs and pharmaceuticals; agricultural chemicals and chemical products; plastic resins and materials; pulp, paper and allied products; iron and steel; metal working machinery and equipment; electrical machinery and equipment; home electronic equipment; and flat glass and glass containers. Specific industry definitions and sources are provided in the

20/Kravis and Lipsey (1971) provide data which also suggest such divergence. However, their data are limited to 6 points in time and could conceivably reflect transitory disequilibria.

Data Appendix. The U.S. wholesale prices are viewed as proxies for U.S. export prices, f.o.b.,[21/] and German mark prices are converted into dollars at spot exchange rates in order to construct ratios of U.S. dollar prices to German dollar prices. The data period spans several major exchange rate shocks and provides evidence on the response of these dollar price ratios to major shocks.[22/]

What do we expect the data to show? If we were looking only at aggregates of homogeneous commodities (such as basic foodstuffs, textile fibers, and metals of specified characteristics) traded actively on competitive markets for which there are daily dollar price quotations for specified delivery dates, we would expect exchange rate shocks to affect these dollar price quotations, but we would never observe any differences in the dollar prices of the same commodity supplied by different countries. However, for fairly homogeneous commodities not traded on organized markets (such as fairly homogeneous specifications of steel plate, lamp plugs, shoelaces, or table salt), we might expect a transitory disruption of the equilibrium between the relative dollar prices for products of

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21/ Ripley (1974) has found high degrees of correlation between movements in U.S. wholesale prices and U.S. export unit values for the broad aggregate of finished manufactures, but not for the broad aggregate of semimanufactures.

22/ Dunn (1970) has studied the response of prices to small fluctuations in the U.S.-Canadian exchange rate. His econometric results show that the differences between percentage changes in Canadian own-currency prices and percentage changes in U.S. own-currency prices are not significantly related to small percentage changes in exchange rates, so that small exchange rate changes do appear to affect relative prices measured in a common currency. However, it cannot be concluded that any permanent effects are substantial. To support this latter conclusion one would need evidence of trends in relative prices measured in a common currency.

different countries.[23/] Over time, on the other hand, we would expect inventory depletion and growth of orders in the country with the relatively-lowest priced product, and inventory accumulation and a decline of orders in countries with relatively-higher priced products, which would induce price adjustments toward a new relative-price equilibrium.[24/]

Thus, while exchange rate shocks may have transitory effects on relative dollar prices of similar products, we expect to observe no permanent trends in the relative f.o.b. dollar prices of homogeneous U.S. and German products, subject to the usual caveats that trends in measured U.S. and German prices accurately reflect trends in true transactions prices, and that trends in relative delivery times and other non-price factors are negligible. This conclusion would extend to relative dollar prices of industry aggregates of homogeneous commodities, provided the U.S. and German industry price indexes assigned the same weights to each commodity, which they unfortunately do not do. Subindustry weights

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23/ Rosenberg (1973) presents an interesting case study of the relative prices of four U.S. and foreign-produced specifications of steel, using data on duty-paid c.i.f. prices at U.S. point of delivery. Dollar price ratios differed from unity, due to differences in non-price factors such as different delivery lags; but "two U.S. devaluations had but a minimal impact on the relative price (p.33)."

24/ Note that the model of market-clearing prices developed in Section 2 ignores adjustments of inventories and orders backlogs and hence, for goods other than those traded activity on organized commodity markets, may not realistically capture the short-run price responses to events that shock supplies and demands.

in the U.S. wholesale price indexes are based on value of shipments data from the 1963 industrial censuses, whereas subindustry weights in the German export price indexes are based on German export values for 1962. Consequently, an exchange rate change might induce permanent shifts in the relative dollar prices of industry aggregates if dollar prices of different subindustries responded in proportionately different amounts to the exchange rate change.

Table 1 suggests that relative dollar prices for U.S. and German industries have in fact shifted substantially and permanently in response to exchange rate changes. Percentage changes in exchange rates and relative dollar price indexes are shown for 4 different intervals and, in the last column, for the data period as a whole. In each case percentage changes are computed between three-month averages, with these three-month end points selected as periods of relatively-little price and exchange rate movements. The first interval starts at the beginning of the data period and ends just prior to the German revaluation in October 1969. On November 23, 1968, Germany imposed a "special turnover tax" of 4 percent on new export contracts (effective until the October 1969 revaluation), which is included in the computed changes in effective exchange rates and relative prices for the first two intervals. The second interval starts just prior to the October 1969 revaluation and ends just prior to the start of the German float in May 1971. The third interval includes the

Table 1: <u>Percentage Changes in Exchange Rates and Relative Dollar Price Indexes over Selected Periods</u>

	Jan-Mar 68 to June-Aug 69[a]	June-Aug 69[a] to Feb-April 71	Feb-April 71 to July-Sept 72	July-Sept 72 to Aug-Oct 73	Jan-Mar 68 to Aug-Oct 73
Exchange Rate 1/KG	-3.91	-5.53	-12.39	-23.86	-39.44
$\frac{PUS}{KG \cdot PG}$ for industry:					
1. Apparel	-4.37	-5.79	-14.33	-27.88	-44.34
2. Industrial Chemicals	-6.33	-3.39	-9.20	-29.83	-42.34
3. Drugs	-3.68	-8.55	-12.95	-22.83	-40.83
4. Agricultural Chemicals	-7.77	+4.69	-8.28	-27.19	-35.52
5. Plastic Materials	-9.71	-9.82	-13.00	-0.50	-29.51
6. Paper Products	-2.04	-0.86	-8.55	-19.08	-28.13
7. Iron and Steel	-10.59	-4.97	-3.79	-27.40	-40.66
8. Metalworking Machinery	-9.64	-17.13	-12.46	-25.10	-50.91
9. Elec. Industrial Equip.	-5.03	-7.21	-13.05	-25.45	-42.88
10. Home Electronic Equip.	-9.91	-7.47	-9.81	-27.70	-45.64
11. Glass Products	+0.47	+3.80	-16.34	-28.04	-37.23

PUS = U.S. wholesale price in dollars.
PG = German export price in marks.
KG = dollar price of one mark spot.

a/ For June-Aug 1969, KG is set 4 percent higher than the spot exchange rate to reflect the effective exchange rate for German exports under the 4 percent export tax levied in November 1968.

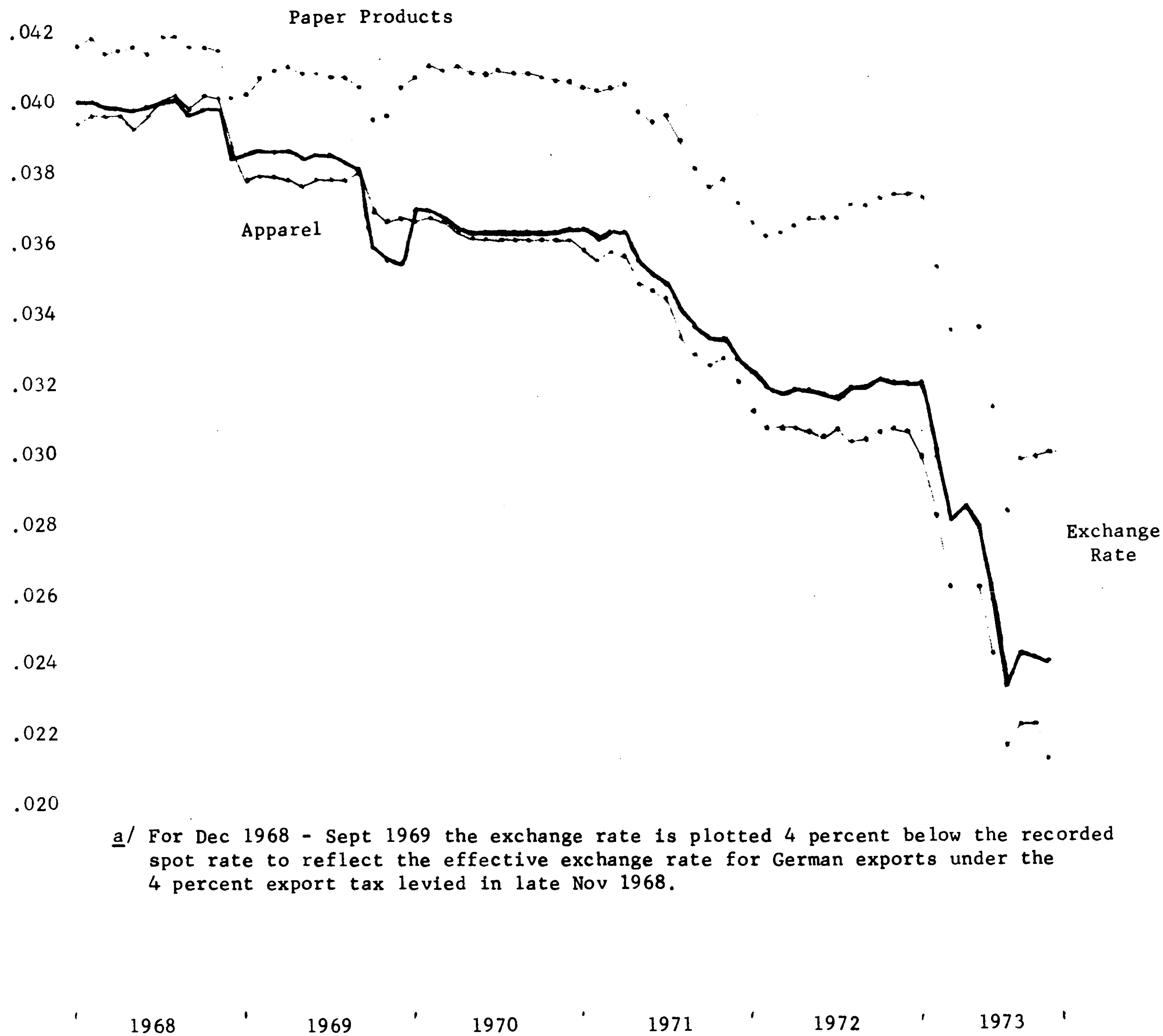
German float, the Smithsonian Agreement in December 1971, and the three quarters following the Smithsonian and ending prior to early signs of the pressures that brought the realignment of February 1973. The fourth interval includes the realignments of first-quarter 1973 and the floating period thereafter, but ends during a three-month period of relatively stable exchange rates.

The table shows that in each of the four intervals, and also for the data period as a whole, more than half of the relative price indexes changed in the same direction and by a greater percentage than the exchange rate. The last column shows that for the data period as a whole, only two industries showed relative price changes substantially smaller than the exchange rate change, with the relative price of paper products showing a smaller percentage change in all four intervals. Figure 1 shows how closely several of the relative price indexes followed the exchange rate.

Can these findings be reconciled with the view that at levels of extreme disaggregation at which goods are fairly homogeneous, most goods are marketed under fairly competitive conditions, and thus have similar dollar prices throughout the world? To some extent they can, under reasonable assumptions about the direction of aggregation bias.

Consider again the fact that subindustry weights in the U.S. wholesale price indexes are proportionate to U.S. base-year values of

Figure 1: RELATIVE DOLLAR PRICE INDEXES AND EXCHANGE RATE[a]



a/ For Dec 1968 - Sept 1969 the exchange rate is plotted 4 percent below the recorded spot rate to reflect the effective exchange rate for German exports under the 4 percent export tax levied in late Nov 1968.

shipments, while subindustry weights in the German export price indexes are proportionate to German base-year export values. If we conjecture that high values of shipments reflect high levels of absorption in the U.S., and that German exports are high in subindustries in which German absorption is also high, then those subindustries which receive relatively greater weights in the U.S. industry price index than in the German industry price index are likely to be subindustries in which U.S. absorption is relatively high in proportion to German absorption; and vice versa. Thus, recalling condition (2.4) of Section 2, subindustries with relatively large weights in any U.S. industry price index are likely to show relatively small dollar price responses to exchange rate changes, while sub-industries with relatively large weights in any German industry price index are likely to show relatively small mark price responses to exchange rate changes. Consequently, the ratio of U.S. to German dollar price indexes for any industry is likely to decline permanently when the mark is revalued.[25]

Until further research is conducted, it is difficult to guess the extent to which aggregation bias explains the large changes in

25/ To illustrate, let there be two sub-industries with weights of .8 and .2 in the U.S. industry price index and .1 and .9 in the German index. Suppose the world consists of these two countries alone, with the U.S. absorbing 75 percent of world supply of sub-industry 1 and 30 percent of sub-industry 2. Revalue the mark by one percent and apply equation (2.4) to estimate that the dollar price of sub-industry 1 rises by .25 percent and the dollar price of sub-industry 2 rises by .70 percent. Hence, the U.S. dollar price index for the industry rises by .34 percent while the dollar price index for the German industry rises by .655 percent. Thus, the ratio of U.S. to German dollar price indexes declines by 31.5 percent of the exchange rate change, even though each sub-industry has a uniform dollar price throughout the world.

relative price indexes that are shown in Table 1. In addition to what may be attributed to aggregation bias, part of these large changes may be transitory, due to long lags in the adjustment of recorded prices. Such lags may have been particularly long under the various regimes of U.S. price controls, which began in August 1971. Any remaining part of the changes in relative prices must be due to monopoly elements, perhaps secured through product differentiation.

5. Some Implications for Aggregative Regression Models

The aggregation bias noted in the previous section has implications for those econometric models which regress domestic price aggregates on import price indexes, or import prices on foreign prices, or export prices on domestic prices.26/ 27/ Consider the simple regression equation

$$\hat{P}_D = \alpha(\widehat{kP_F}) + u = \alpha(\hat{k}+\hat{P}_F) + u \qquad (5.1)$$

26/ In addition, such aggregation bias raises serious questions about the stability of elasticities of substitution estimated from industry or more-aggregated data. If the output of tradeable goods industries could be disaggregated into homogeneous competitively-marketed commodities, then finite values of estimated substitution elasticities could be attributed entirely to aggregation bias. Such estimates might only be useful for prediction purposes if one could safely neglect changes in the extent of aggregation bias.

27/ It is also interesting to note that within a world consisting entirely of homogeneous competitively-marketed goods, aggregation bias could explain the "correct signs" on relative price variables that are estimated under conventional but inappropriate specifications of import demand functions.

in which

P_D = domestic price index

P_F = foreign price index

k = domestic-currency price of foreign-currency

u = stochastic error

$\wedge$ denotes a proportionate rate of change

If the economy could be disaggregated into a set of homogeneous competitively-marketed goods with uniform common-currency prices throughout the world, and if each good received equal weights in the domestic and foreign price indexes, then (5.1) would be an identity with $\alpha = 1$. Suppose, however, that the former condition is true, but that goods receive unequal weights in P_D and P_F. For example, consider a two-good, two-country world in which the price of good 1 receives respective weights of .8 and .1 in P_D and P_F, while the price of good 2 receives respective weights of .2 and .9. Under conditions of uniform world inflation, with domestic and foreign prices of both goods increasing at uniform rates and the exchange rate stable, α would equal 1, with no aggregation bias. However, following an exchange rate shock, the proportionate change in kP_F would be likely to exceed the proportionate change in P_D due to aggregation bias, with an implied α less than 1. In particular, using the parameter values of footnote 24, P_D would rise by 34 percent of the percentage devaluation of country D's currency, and kP_F would rise by 65.5 percent of the devaluation, implying an α equal to .52.

Consider now a time period during which there are changes in the relative importance of these two phenomena --- that is, the phenomena of uniform inflation independent of exchange rate fluctuations and differential inflation (by commodity) due entirely, say, to exchange rate changes. During such time periods, $\widehat{kP_F}$ would not be a good predictor of $\hat{P}_D$ without additional knowledge of the phenomena generating $\widehat{kP_F}$. Estimation of (5.1) would yield an estimated α less than 1, but possibly unstable.

The problem is not adequately resolved by respecifying the model as

$$\hat{P}_D = \alpha_1\hat{k} + \alpha_2\hat{P}_F + u \qquad (5.2)$$

because $\hat{P}_F$ is not independent of $\hat{k}$. We might imagine $\hat{P}_F$ to be a linear combination of the above two phenomena (with coefficient on $\hat{k}$ based on footnote 24)

$$\hat{P}_F = \hat{P}_0 - .345\hat{k} \qquad (5.3)$$

where $\hat{P}_0$ represents a hypothetical rate of uniform inflation independent of exchange rate fluctuations. In this case we could substitute (5.3) into (5.1) to get

$$\hat{P}_D = \alpha(1-.345)\hat{k} + \alpha\hat{P}_0 + u \qquad (5.4)$$

and we would then expect to estimate α=1. More generally, if the coefficient on $\hat{k}$ in (5.3) were unknown, we might want to estimate

$$\hat{P}_D = \beta\hat{k} + \alpha\hat{P}_0 + u \qquad (5.5)$$

if $\hat{P}_0$ could be quantified, rejecting any results that did not estimate $\alpha=1$. However, this is not the appropriate procedure if our framework is a world consisting of homogeneous competitively-marketed goods. Rather, we should return to specification (2.2), appropriately aggregated over commodities. Changes in domestic price indexes should be regressed on exchange rate changes and the policy instruments and other important variables which affect supplies and demands throughout the world.

Data Appendix

U.S. wholesale price indexes were taken from various issues of the Monthly Labor Review (U.S. Department of Labor, Bureau of Labor Statistics). In most cases these are constructed from f.o.b. prices at production or central marketing point. Weights are based on value of shipments data from the 1963 industrial censuses. The price indexes are scaled to 1967=100.[1/]

German export price indexes were taken from Preise Löhne Wirtschaftrechnungen Reihe 1: Preise und Preisindices für Aussenhandelsgüter (Statistiches Bundesamt Wiesbaden, 1972 edition and 1973 monthly issues, Table 2b: "Index der Verkaufspreise für Ausfuhrgüter: Gleiderung nach dem produktionswirtschaftlichen Zusammenhang"). Prices are generally collected on an f.o.b. basis and in all cases are duty free. Weights are based on German export values for 1962, and the price indexes are scaled to 1962=100.

Foreign exchange rates for the Deutschemark vis-a-vis the dollar were taken from various issues of the Federal Reserve Bulletin. These are spot rates measured in cents per Deutschemark, computed as monthly averages of noon buying rates in New York for cable transfers.

The eleven industries, their respective titles in the U.S. and German data sources, their U.S. wholesale price codes in parentheses, and other relevant specifics are as follows:

1. Apparel (03-5); Bekleidung (zusammen).

1/ For a more complete description, see U.S. Department of Labor, Bureau of Labor Statistics, BLS Handbook of Methods, Bulletin 1711, 1971, Chpt. 11.

2. Industrial chemicals (06-1); weighted average of Anorganische and Organische Grundstoffe und Chemikalien. The weights used to combine the German series were .4250 (inorganic) and .5750 (organic), based on the relative weights of these items in the U.S. wholesale price index.[2/]

3. Drugs and pharmaceuticals (06-3); Pharmazeutische Erzeugnisse.

4. Agricultural chemicals and chemical products (06-5); Düngemittel und Schädlingsbekämpfungsmittel.

5. Plastic resins and meterials (06-6); Kunststoffe.

6. Pulp, paper and allied products (09); Papier und Pappewaren.

7. Iron and steel (10-1); weighted average of (a) Erzeugnisse der Eisenschaffenden und Ferroleigierungs Industrie (zusammen), (b) Geissereierzeugnisse: Eisen-Stahl-und Temper-guss, and (c) Erzeugnisse der Ziehereien, Kaltwalzw. und d. Stahlverformung (zusammen). The weights used to combine the three German series were (a) .0544, (b) .1833 and (c) .7623, based on the relative weights assigned to items (a) 10-11 plus 10-12, (b) 10-15, and (c) 10-13 in the U.S. wholesale price index.[3/]

8. Metal working machinery and equipment (11-3); Metallbearbeitungsmaschinen (zusammen).

9. Electrical machinery and equipment (11-7); weighted average of Geräte und Einrichtungen (a) zur Elektrizitätserzeugung and (b) zur Elektrizitätsverteilung. The weights used to combine the German series were (a) .4983 and (b) .5017, based on the relative weights assigned to

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2/ Source: U.S. Department of Labor, Bureau of Labor Statistics, Wholesale Prices and Price Indexes: Supplement 1972, Feb. 1973, Table 4.

3/ Source: Ibid.

items (a) 11-73 plus 11-74 and (b) 11-71 plus 11-75 in the U.S. wholesale price index.4/

10. Home electronic equipment (12-5); Rundfunk - Fernseh - phonotechn. Geräte und Einrichtungen.

11. Flat glass plus Glass containers (13-11 plus 13-8); Glas und Glaswaren (zusammen).

4/ Source: Ibid.

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