A Method For Separating Income & Substitution Effects Of Exchange Rate Changes

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ABSTRACT

Regression coefficient estimates of exchange rate total effects on aggregate demand are broken into separate income and substitution effects. Total effect (substitution and income) regression estimates can seem contrary to theory and common sense. Separating them into their two components shows this is not the case. The separation method also provides a simple test to determine if imports are normal or inferior goods. The paper finds consumer imports are normal goods, investment imports are inferior goods. The paper shows that if import total effects exceed domestic total effects, imports are a normal good. If smaller, they are inferior goods. (JEL: E00, F40, F43)

INTRODUCTION: CONSUMER DEMAND

A recent study indicated the U.S. exchange rate was systematically related to the level of consumer spending, particularly on imports (Heim 2008). In this study, demand for domestically produced or imported consumer goods was regressed on a range of variables commonly held to be determinants of consumer spending, including disposable income, interest rates, consumer wealth and the relative price of imports compared to domestic goods, as measured by the exchange rate. Higher exchange rate values indicate more foreign currency can be bought per dollar, which in turn can mean cheaper import prices. An additional determinant, measured by the government deficit, provides a measure of the extent to which consumers are crowded out of the credit market by government borrowing. The spending and tax variables are reported separately, rather than as a net figure, since preliminary testing indicated deficit increases due to increased government spending restrict consumer credit less than tax cuts. Key regression findings are summarized in the equations in table 1.

Subscripts of zero on variables, or no subscripts at all, mean the current period value of the variable is used. Subscripts with negative signs indicate the number of years the variable is lagged. The equations are estimated using first differences of the data e.g., $\Delta(C)_0$ to help reduce multicollinearity and autocorrelation problems, and sometimes non-stationarity problems in otherwise highly correlated data.

Adding the exchange rate variable seemed to have a major influence on demand for imported consumer goods, adding 6%-points to explained variance. However, explained variance did not increase in the other two models. These exchange rate coefficients show the total effect of an exchange rate change on consumer demand. Below this effect will be separated into its income and substitution effect components.

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Table 1: The Determinants of Demand for Total, Imported and Domestically Produced Consumer Goods (Nominal Exchange Rate Used)

$\Delta(C)_0$	$=.63\Delta(Y\text{-}T_G)_0$	$+.47\Delta T_{G(0)}$	$+ .06\Delta G_0$	$– 6.22\ \Delta\ PR_0.$	$+.60\ \Delta DJ_{-2}$	$+ 2.69\ \Delta XR_{AV0123}$	R^2=91%
(t)	(18.2)	(4.3)	(0.5)	(-3.4)	(4.0)	(1.5)	D.W.= 1.7
$\Delta(M_{m\text{-}ksm})_0$	$=.06\Delta(Y\text{-}T_G)_0$	$+.27\Delta T_{G(0)}$	$-.18\ \Delta G_0$	$– 3.94\ \Delta PR_0.$	$+ .26\ \Delta DJ_{-2}$	$+ 4.33\ \Delta XR_{AV0123}$	R^2=83%
(t)	(2.8)	(4.6)	(-1.9)	(-2.6)	(1.8)	(2.9)	D.W.= 1.5
$\Delta(C\text{-}\ M_{m\text{-}ksm})_0$	$=.57\Delta(Y\text{-}T_G)_0$	$+.20\Delta T_{G(0)}$	$+.24\ \Delta G_0$	$– 2.28\ \Delta PR_0.$	$+ .34\Delta DJ_{-2}$	$-\ 1.64\ \Delta XR_{AV0123}$	R^2=74%
(t)	(16.0)	(1.6)	(1.3)	(-0.7)	(2.8)	(-1.0)	D.W.= 1.8

Where

C = Total Consumption

$M_{m\text{-}ksm}$ = Consumer Imports

$C\text{-}\ M_{m\text{-}ksm}$ = Consumer Goods Domestically Produced

$Y\text{-}T_G$ = Disposable Income

T_G = Government Receipts

G_0 = Government Spending on Goods & Services

PR_0 = Real Prime Interest Rate

DJ_{-2} = A Wealth Measure: the Dow Jones Composite Average

XR_{AV0123} = The average nominal exchange rate (trade weighted) for the current and past three Years

The Federal Reserve's trade weighted nominal Broad exchange rate was used above; a related study (Heim 2009) used the Federal Reserve's real Broad exchange rate in the same models, and yielded similar results except the exchange rate variable, whose results varied somewhat, as expected.

Table 2: The Determinants of Demand for Total, Imported and Domestically Produced Consumer Goods (Real Exchange Rate Used)

$\Delta(C)_0$	$=.66\Delta(Y\text{-}T_G)_0$	$+.49\Delta T_{G(0)}$	$+ .04\Delta G_0$	$– 6.92\ \Delta PR_0.$	$+.62\ \Delta DJ_{-2}$	$+ 2.83\ \Delta XR_{AV0123}$	R^2=92%
(t)	(29.2)	(5.7)	(0.3)	(-3.2)	(4.9)	(3.2)	D.W.= 2.0
$\Delta(M_{m\text{-}ksm})_0$	$=.11\Delta(Y\text{-}T_G)_0$	$+.30\Delta T_{G(0)}$	$-.20\ \Delta G_0$	$– 5.00\ \Delta PR_0.$	$+ .34\ \Delta DJ_{-2}$	$+ 3.03\ \Delta XR_{AV0123}$	R^2=85%
(t)	(6.3)	(5.0)	(-2.0)	(-3.5)	(4.5)	(5.6)	D.W.= 1.8
$\Delta(C\text{-}\ M_{m\text{-}ksm})_0$	$=.55\Delta(Y\text{-}T_G)_0$	$+.19\Delta T_{G(0)}$	$+.24\ \Delta G_0$	$– 1.92\ \Delta PR_0.$	$+ .28\Delta DJ_{-2}$	$-\ .20\ \Delta XR_{AV0123}$	R^2=74%
(t)	(16.2)	(1.5)	(1.3)	(-0.6)	(1.9)	(-0.2)	D.W.= 1.8

Adding the exchange rate variable to the total, imports, and domestically produced consumer goods models above increases explained variance by 2%, 8% and 0% respectively. Notice the estimated total effect of exchange rates on consumer demand for imports is larger than the estimated total effect on domestic goods, and that the estimated total effect on domestic goods is negative. Later we will show that this implies consumer imports are normal goods and that the substitution effect outweighs the income effect.

INTRODUCTION: INVESTMENT DEMAND

Similarly, the (2008a) study indicated the exchange rate played the following role in determining the level of spending on domestic and imported investment goods:

Table 3: The Determinants of Demand for Total, Imported and Domestically Produced Investment Goods (Nominal Exchange Rate Used)

ΔI	$=.28\Delta ACC +$	$.95\Delta DEP +$	$1.48\Delta CAP_{-1} +$	$.52\ \Delta T_G$	$-.63\Delta G\ -$	$6.40\Delta PR_{-2}$	$-.20\ \Delta DJ_{-2}$	$+.16\ \Delta PROF_{-2}$	$+ 6.92\ \Delta XR_{AV0123}$	$R^2=.89$
t=	(7.9)	(3.2)	(1.0)	(5.6)	(-2.9)	(-3.8)	(-0.8)	(0.9)	(3.8)	DW =1.9
$\Delta(M_{ksm})$	$=.04\Delta ACC +$	$.38\Delta DEP +$	$1.52\Delta CAP_{-1} +$	$.07\ \Delta T_G$	$-.22\Delta G\ +$	$1.54\Delta PR_{-2}$	$+.19\Delta DJ_{-2}$	$-\ .10\ \Delta PROF_{-2}$	$+ 2.52\ \Delta XR_{AV0123}$	$R^2=.70$
t=	(1.8)	(4.1)	(2.2)	(2.5)	(-2.1)	(1.3)	(2.6)	(-1.1)	(-2.1)	DW =2.4
$\Delta(I-M_{ksm})$	$=.24\Delta ACC +$	$.57\Delta DEP -$	$.04\Delta CAP_{-1} +$	$.44\ \Delta T_G$	$-.41\Delta G\ -$	$8.00\Delta PR_{-2}$	$-.38\ \Delta DJ_{-2}$	$+.26\ \Delta PROF_{-2}$	$+ 4.39\ \Delta XR_{AV0123}$	$R^2=.85$
t=	(8.7)	(1.9)	(-0.0)	(5.4)	(-2.0)	(-4.9)	(-1.5)	(1.5)	(1.8)	DW =1.6

Where

- I = Total Investment Demand
- M_{ksm} = Demand for Imported Investment Goods
- $I-M_{ksm}$ = Demand for Domestically Produced Investment Goods
- ACC = The Accelerator, a measure of the growth rate of the GDP each year
- DEP = Depreciation Levels of Capital Equipment
- CAP_{-1} = % of manufacturing capacity currently being utilized, lagged one year
- $\Delta PROF_{-2}$ = Corporate profits, lagged two years

Other variables used are defined in the consumption equations. Subscripts have the same meanings as before and first differences of the data are again used. Notice that, unlike the consumption equations, in the investment equations the larger estimated total effect of a change in exchange rates on demand is in the domestic demand equation, not import demand. We will show later that this is a sign that investment imports are inferior goods.

These coefficients estimates of the exchange rate total effects will be separated below into income and substitution effects. The exchange rate does add significantly to the explanatory power of some equations. The exchange rate appears to have a major influence on demand for imported investment goods, adding 6%-points to explanatory power, but also adds 4% to explained variance when added to the total investment demand and 2% to domestically produced investment goods demand models.

We note that the regression results indicate that for every single - point (~ 0.8%) decline in nominal Broad exchange rate from 2000 levels, making imports more expensive, there appears to be a $4.39

billion decrease in demand for domestically produced investment goods as well as a 2.52 billion decrease in demand for imported investment goods. We will show later this finding for domestic goods is not nearly as irrational as it appears to be at first blush. It is totally consistent with our estimates of the sum of income and substitution effects for investment goods, particularly our estimates showing investment goods, as a group, are inferior goods and that this trait is transmitted through the substitution effect.

Results for the same investment demand model using the real Broad exchange rate (Heim 2009), are presented in Table 4 below. They were very similar; with the total effect estimates above not changing much for any of the variables, except the exchange rate, which was expected:

Table 4: The Determinants of Demand for Total, Imported and Domestically Produced Investment Goods (Real Exchange Rate Used) .

ΔI	$=.28\Delta ACC$ +	$1.37\Delta DEP$ +	$.69\Delta CAP_{-1}$	$+.52\ \Delta T_G$	$-.61\Delta G$	$-\ 8.46\Delta r_{-2}$	$-.10\ \Delta DJ_{-2}$	$+.35\ \Delta PROF_{-2}$	$+\ 4.97\ \Delta XR_{AV0123}$	$R^2=.89$
t=	(6.9)	(4.7)	(0.4)	(5.3)	(-3.4)	(-3.5)	(-0.4)	(2.0)	(4.2)	DW =2.3
$\Delta(M_{ksm})$	$=.05\Delta ACC$ +	$.46\Delta DEP$ +	$1.25\Delta CAP_{-1}$	$+.07\ \Delta T_G$	$-.14\Delta G$	$+\ 1.12\Delta r_{-2}$	$+.30\ \Delta DJ_{-2}$	$-\ .11\ \Delta PROF_{-2}$	$-\ .40\ \Delta XR_{AV0123}$	$R^2=.64$
t=	(1.9)	(4.5)	(1.4)	(2.0)	(-1.7)	(0.7)	(3.4)	(-1.09)	(-0.7)	DW =2.1
$\Delta(I-M_{ksm})$	$=.24\Delta ACC$ +	$.91\Delta DEP$	$-.15\Delta CAP_{-1}$	$+.45\ \Delta T_G$	$-.47\Delta G$	$-\ 9.59\Delta r_{-2}$	$-.40\ \Delta DJ_{-2}$	$+.47\ \Delta PROF_{-2}$	$+\ 5.37\ \Delta XR_{AV0123}$	$R^2=.88$
t=	(7.8)	(3.0)	(-0.4)	(6.0)	(-2.9)	(-7.3)	(-1.9)	(4.1)	(4.1)	DW =2.1

Adding the exchange rate variable increases explained variance in the total, imports and domestically produced goods models by 4, 0 and 5% respectively.

Ultimately, the sign of the total effect of an exchange rate change on spending is the sum of its two parts: the "pure" income effect and the substitution effect. If the substitution effect is negative, and large, it may "swamp" the positive income effect, and leave a negative sign. If not, the sign may be positive. For example, by separating the total effects of a change in exchange rates in tables 1-4 above into their separate income and substitution effects, we can explain results which otherwise seem illogical, or at least puzzling. We (again) note that the regression results indicate that for every single - point decline in the nominal exchange rate (imports more expensive) there appears to be a $4.39 billion decrease in demand for domestically produced investment goods and a 2.52 billion decrease in demand for imported investment goods. The decrease in import demand is understandable since if import prices are increasing, the real income effect is negative. Further, if investment goods are normal goods, the increase in relative import prices should cause further movement out of imports. However, we do not find demand for domestically produced investment goods increases. This may be because the negative income effect swamps the positive substitution effect, or if imports are an inferior good, the overall effect may be out of domestic goods because both effects are negative. To know for certain, we must parse out the separate income and substitution effects.

There is a simple method for breaking down the total effect of an exchange rate change into its income effect and substitution effect components, so that we can resolve such questions. The method will use information we already have on the estimated total effect of exchange rate changes on and the information inherent in the following identities for domestic (D) and imported (M) goods:

Total \$ Effect (T_D) = \$ Income Effect (I_D) + \$ Substitution Effect (S_D)

Total \$ Effect (T_M) = \$Income Effect (I_M) + \$ Substitution Effect (S_M)

Since economic theory holds that *the real value* of (pure) substitution effects are symmetric except for sign, this means that in money terms

$$S_D = -(S_M)$$

i.e.,

$$T_D - I_D = -(T_M - I_M)$$

Since T_D and T_M are known from regression analysis, this leaves us with one equation in two unknowns: I_D and I_M, *the dollar value* of the pure income effect. However, we will show that these two pure income effects must be the same. Therefore, we have but one equation in one unknown to solve, which is a simple task. This will be done further below.

OTHER EMPIRICAL ESTIMATES OF INCOME AND SUBSTITUTION EFFECTS: A LITERATURE REVIEW

Elmendorf (1996) has excellent estimates the total effect of changes in interest rates on consumption, but does not break them down into income and substitution effects. Baker, Gruber and Milligan (2003) examined the impact of Canada's government retirement programs on work incentives, but, again, did not attempt to separate the total effect of the onset of retirement income into income from substitution effects. Others have attempted to separate these two effects, but have used "hypotheticals", such as "what if" survey responses, instead of data to estimate one of the effects. The other effect is then inferred from indirect evidence. For example, Kimball and Shapiro (2008) estimated income effects of a income increase by asking survey respondents "what if" they won a sweepstakes. How would their work habits change if they won an independent income for life? Using these responses as "income effects", restrictions from labor theory, and known total effects of approximately zero, they inferred substitution effects of a magnitude similar to income effects. Ward and Worach (2005) examined whether the cheaper price of land line phone service available to low income people ("Lifeline" service) affected their demand for cell phone services compared to others. They found a 17.8% difference before controlling for income and demographic characteristics. After controlling for these factors, only 3.1% remained. Since they had attempted to control for income, they were inclined to view the remaining 3.1% as a substitution effect. To ensure the 3.1% was not some contaminated by some residual income effect mixed in, they examined usage of other communication services (cable TV and internet) and income level. When income and demographic characteristic were controlled for, they could not find any significant remaining relationship between usage of cable TV or internet, and usage of the "lifeline' service by poor people. They concluded the 3.1% effect was the substitution effect.

INCOME AND SUBSTITUTION EFFECTS IN THEORY

In standard economic theory, utility is derived from consumption. Utility varies as the combination of goods consumed changes. The combinations considered here are domestically produced goods and imported goods. (D) represents the bundle of domestically produced goods consumed by businesses (investment goods) or consumers (consumer goods); (M) represents the bundle of investment or consumer imports. The utility relationship is given as

$$\text{Utility (U)} = f\,(D, M)$$

One example of this relationship might be

$$U = D*M$$

$$\rightarrow \quad D = U/M$$

i.e., utility grows in both D, M subject to diminishing returns. This function provides us with an example of a standard – shaped hyperbolic indifference curve in which U is increasing in D, M.. For example, we might find (were utility cardinally countable),

$$U = 100 = D_{10} *M_{10}$$

$$U = 400 = D_{20} *M_{20}$$

Where the subscripts on D, M represent the real quantities consumed. Consumers (and businesses) choose utility maximizing combinations of D and M, given their budget constraints

$$P_D*D = \text{Budget (B)} - P_M*M$$

If the budget is 20 and prices are $P_D = P_M = \$1$, the feasible combinations of goods the consumer can buy with a the budget is given by (D = 20 – M), where "20" might be interpreted as $20 billion and U =100 at utility maximization. The combination of goods that fully expends the budget and provides the highest utility level is D=10 and M=10. Other purchasable combinations provide lower utility, for examples

$D_{=18} = 20 - M_{=2} = \rightarrow \quad U = 15*5 = 36$

$D_{=15} = 20 - M_{=5} = \rightarrow \quad U = 15*5 = 75$

$\underline{D_{=10} = 20 - M_{=10} = \rightarrow \quad U = 10*10 = 100}$

$D_{=5} = 20 - M_{=15} = \rightarrow \quad U = 15*5 = 75$

$D_{=2} = 20 - M_{=18} = \rightarrow \quad U = 15*5 = 36$

Etc….

We can see the *dollar amounts of each good which maximize utility are the same*: ($1*D = $1*M =10). In this specific case, the quantities are also the same. In the more general case dollar equivalence will remain, but quantity equivalence will not. Theory suggests the ratio of the goods selected is inversely related to the ratio of their prices, which implies that for budget (income level) changes, prices remaining constant, utility maximization requires allocation of equal money amounts to both products when income changes. This is true for any income change, from zero income on up. We can measure this "pure income effect" by simply increasing the consumer's budget without changing the relative prices of (D,M). If income doubles, the vertical and horizontal intercepts on the budget constraint double, but the slope of the budget line (P_M/P_D) remains the same. It now touches the new (and higher) indifference curve where the new curve has the same marginal rate of substitution (MRS) as before. Therefore, both before and after the change

$$MRS = \partial D/\partial M = P_M/P_D \quad \text{(Prager, 1993)}$$

Which implies $\partial D^*P_D = \partial M^*P_M$

Or in discrete terms $\Delta D^*P_D = \Delta M^*P_M$

Clearly this indicates that (except for sign) the money value of substitution effects must be identical. The dollar amount substituted out of one good must equal the amount substituted into the other.

This formulation also clearly indicates that if incomes change *not due to price changes, i.e., prices remaining constant*, we have a “pure income effect”. In order for the above condition above to be met if income is increasing, *spending on both goods must change by the same amount*, no matter what the initial income level. This must hold for all budget levels, e.g.,

$\Delta 1D^*P_D = \Delta 1M^*P_M$

$\Delta 2D^*P_D = \Delta 2M^*P_M$

$\Delta 3D^*P_D = \Delta 3M^*P_M$

Etc.…

Hence we conclude this standard theoretical formulation shows that the money value of the “pure” income effect must be the same for two goods when income changes, prices constant. The money value of pure substitution effects are also the same (except for sign). These two findings are of key importance in inferring income and substitution effects from data on total effects.

INVESTMENT DEMAND: DERIVING INCOME AND SUBSTITUTION EFFECTS FROM ESTIMATED TOTAL EFFECTS:

Six cases are evaluated to determine income and substitution effects of exchange rate changes on investment goods. An additional six cases test consumer goods in the same way.

- Cases 1 and 3 test, whether imported investment goods, as a group, are normal goods. Nominal and real exchange rate changes are tested separately).
- Cases 2 and 4 test whether imports should be considered an inferior good, with the inferiority trait passing through the substitution effect (again, nominal and real exchange rates changes are tested separately).
- Finally, a fifth and sixth cases are tested. They test the hypothesis that imports are inferior goods, but that the inferiority trait passes through the income effect. Again, separate tests are run using the nominal and real exchange rates.

Using the method described, these six tests, applied separately to investment and consumption, lead this study to conclude

- consumer imports are normal goods (as a macroeconomic grouping).

- investment imports are inferior goods (as a macroeconomic grouping), with the inferiority trait passing through a negative substitution effect.

Details of these tests, as well as a more complete exposition of the theory, are published in the full version of this paper under the same title in the *Journal of International Finance and Economics*, Vol. 9 (3), Oct. 2009, pp. 69-82.

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