Exchange Rate Pass-Through, Markups, and Inventories

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Abstract

A large body of research has established that exporters do not fully adjust their prices across countries in response to exchange rate movements, but instead allow their markups to vary. But while markups are difficult to observe directly, we show in this paper that inventory-sales ratios provide an observable counterpart. We then find evidence that inventory-sales ratios of imported vehicles respond to exchange rate movements to a degree consistent with pass-through on the order of 50 to 75 percent, on the high end of the range found in the literature.

A large literature has established that prices of exported goods typically do not respond one–for–one with movements in the exchange rate between the currencies of the exporting and destination countries. Economists have explored a variety of explanations for this "incomplete pass-through," and the resulting violations of the so-called Law of One Price. While these analyses have reduced the magnitude of the puzzle—for example, by quantifying the portion of value added in the destination country,[1] or by identifying changes in marginal cost—there remains a residual that suggests firms absorb fluctuations in their price-cost markups induced by exchange rates.

The unsatisfying aspect of the fluctuating markup story is that while some models have been developed (e.g. Atkeson and Burstein, 2008; Drozd et al 2010) to suggest reasons why firms might let their markups move with exchange rates, markups themselves are difficult to observe directly. Moreover, the allocative impact of such markup movements is unclear and depends on their underlying cause. Are firms actively reoptimizing, or are they merely operating in some zone of indifference in which they passively let margins (and presumably profits) vary? Given the persistence of exchange rate movements, the latter would seem unlikely, but the question has received less direct attention, tied in as it is with the mechanism for incomplete pass-through.

To address these issues, in this paper we examine the response of motor vehicle inventories to changes in exchange rates. The stockout-avoidance model of inventory behavior (as in Kahn, 1987; Bils and Kahn, 2000) implies that inventory-sales ratios should be positively related to markups, because markups represent the opportunity cost of foregone sales.[2] Consequently, changes in markups induced by exchange rate movements should themselves induce corresponding movements in inventory-sales ratios. If, on the other hand, the apparent incomplete pass-through actually reflects unobserved cost movements, so that markups are not actually changing, movements in exchange rates should not induce relative shifts

[1] Goldberg and Verboven (2004) suggest that "local costs"—presumably denominated in the destination country's currency—are on the order of 35 to 40 percent of total value added.

[2] Bils and Kahn (2000) show a striking example of this phenomenon using tobacco industry data from the 1990s.

in inventory-sales ratios. Thus inventory-sales ratios can provide an indirect measure of markups that does not require data on (or proxies for) marginal cost.

Finally, while it is clear from inventory models that an *exogenous* shift in the markup will shift the desired inventory-sales ratio in the same direction, markups are presumably endogenous. Consequently it is preferable to examine the predictions of a model in which plausibly exogenous shocks drive both markups and inventory-sales ratios. Such a model provides at least a coherent framework for interpreting the data. In our model, firms optimally choose both markups and inventories to maximize profits, and we can show under plausible assumptions that relative inventory-sales ratios (by country-of-origin) move one-for-one with relative markups in response to relative cost shocks.

After a brief literature review in Section I, we describe the model in Section II, and illustrate quantitatively with numerical examples. Section III describes automobile industry data that we then use in a "difference-in-differences" style estimation of the impact of exchange rates on inventory-sales ratios. We find statistically significant evidence that pass-through is incomplete, though of somewhat larger magnitude than has been typically found. That is, we find, for example, that an appreciation of the dollar against the home currency of automobile exporters to the U.S. results in an increase in the U.S. inventory-sales ratio for the exporter relative to the inventory-sales ratios of U.S. firms). According to the model, this indicates an increase in the markup for the exporter relative to the U.S. producer. The pattern of pass-through by country of origin (less for Japan, more for Germany) is similar to other findings in the literature. The magnitude of the increase, however, suggests pass-through of more than 50 percent, even for Japan, which is somewhat larger than most researchers have found, and suggests that there may be important unobserved movements in marginal cost.

1 The Literature on Incomplete Pass-Through

Modern discussion of pervasive violations of the Law of One Price (LOP) date back at least 25 years, e.g. Mann (1986), Krugman (1987), Froot and Klemperer (1989), and Marston (1990), just to name a few.[3] The basic test of LOP is to examine whether identical or very similar goods sell at different prices in different places to a degree that cannot be explained by transport costs or local value added. The presumption is that there is some segmentation in markets that allows such price differentials to persist. While this concept is logically distinct from the issue of exchange rate pass-through (indeed it could be examined within a country or common currency area across regions), the response of prices to exchange rate movements is a natural testing ground for the LOP. Incomplete pass-through also presents additional challenges: Static violations of LOP are easily explained by market segmentation, with markups varying cross-sectionally according to local demand elasticities. For the markup on a particular good in one location to change requires an explanation of how an exchange rate movement or other shock results in a change in the desired markup. Assuming it is not simply price stickiness, this requires something like a change in the demand elasticity. In addition, there are measurement challenges. Since exchange rate movements could be correlated with other shocks, it is necessary either to identify those shocks or to have some measure of marginal cost, either a direct measure or something like a price in more than one location.

Goldberg and Knetter (1997) summarize the findings of this literature:

> "[I]t appears that the local currency prices of foreign products do not respond fully to exchange rates. While the response varies by industry, a price response equal to one-half the exchange rate change would be near the middle of the distribution of estimated responses for shipments to the U.S."

[3] Goldberg and Knetter (1997) summarize the early literature. More recently, Hellerstein (2008) examines the beer industry and finds that roughly half of incomplete passthrough is accounted for by markup adjustments.

The variation in pass-through across industries and products suggests paying particular attention to studies of the automobile industry, as this will be the focus of our empirical work. Fortunately there have been a number of such studies. Here it is worth noting that even within this industry the degree of pass-through is highly variable. For example, Gagnon and Knetter (1995) find that Japanese producers passed through only about 20 percent of exchange rate changes into their export prices, while Germany passed through 80 to 90 percent for larger vehicles and 40 percent for smaller ones (perhaps due to more competition with the Japanese). Similarly, Goldberg (1995) finds 15 to 30 percent pass through for the Japanese, 60 to 100 percent for Germany. In subsequent work, Goldberg and Verboven (2001) examine the European automobile industry. While it is unclear that results from the very different competitive environment of the European market extend to the U.S. market, they find significantly incomplete pass-through, typically less well under 50 percent. More recent work, such as Hellerstein and Villas-Boas (2010) explains this variation in pass-through rates not by country of origin but by structural factors related to market power, such as the degree of vertical integration. They also find a wide range of pass-through rates, ranging from near zero to over 60 percent.

2 Production, Sales, and Inventory with Trade

This section introduces the model that we will use to describe the equilibrium response of a durable goods-producing industry to various shocks. We draw on the work of Atkeson and Burstein (2008, hereafter AB) and Bils and Kahn (2000, hereafter BK). It is a partial equilibrium model, since the focus is one industry that produces a variety of goods. The overall structure is that consumers buy a final good produced by a competitive firm which uses output from a continuum of sectors z_j, for $j \in [0, 1]$. In each sector, there are $2K$ firms producing. The first K firms are domestic and face wage w_D, while the second K firms are foreign and face wage w_F. As we will be examining automobile industry date, a range of sectors could represent types of automobiles (compact, light trucks, etc.) with a finite number of producers within each sector. In the background there is a representative consumer who purchases a consumption aggregate c_t at price P_t from a competitive supplier, based on wealth and expected future income. The partial equilibrium aspect of the model means that we will not concern ourselves with this decision and simply condition our sectoral results on c_t.

2.1 Aggregation of sector outputs into final consumption good

There is a competitive final goods producer that uses sector outputs z_j, $j \in [0,1]$, as inputs to the final consumption good according to the technology

$$c_t = \left[\int_0^1 z_{jt}^{(\eta-1)/\eta} dj \right]^{\eta/(\eta-1)}.$$

As is standard, the firm's demand for z_{jt} takes the form

$$\frac{z_{jt}}{c_t} = \left(\frac{p_{jt}}{P_t} \right)^{-\eta} \tag{1}$$

where

$$P_t = \left[\int_0^1 p_{jt}^{1-\eta} dj \right]^{1/(1-\eta)}.$$

and p_{jt} is the price of z_{jt} as determined below.

2.2 Goods production by manufacturers

There are $2K$ manufacturers in each sector. The first K firms are domestic and the second set of K firms are foreign. Each firm has different productivity, A_{jk} which is constant over time. Assume that $\log A_{jk} \sim N(0, \theta)$, where θ is a parameter. Foreign firms differ from domestic firms in two ways. They pay a different wage and they must also contend with an exchange rate (an exogenous random variable). Firms are monopolistically competitive.

A firm k's output is given by q_{jkt}. They do not necessarily sell what they produce, and consequently may carry inventory over from one period to the next. We will suppose, following Bils-Kahn (2000), that having stock available for sale a_{jkt} has a positive impact on sales x_{jkt}, through better matching of varieties to buyers' preferences or avoiding stockouts. Essentially, the firm chooses a_{jkt} (and hence q_{jkt}) and sets p_{jkt} as of date $t-1$, and then sales x_{jkt} are realized.

2.3 Firm's problem

Firms have constant return to scale production functions were labor is the only input. Production is given by

$$A_t l_t$$

where l_t is the labor input at time t. Domestic firms face wages w_t^D at time t, while foreign firms face wages w_t^F. Given a wage w_t, the marginal cost of production is equal to w_t/A_t.

We make the following assumption about firms and their economic environment:

1. Goods are imperfect substitutes ($\rho < \infty$).

2. Goods within a sector are more substitutable than goods across sections ($1 < \eta < \rho$).

3. Firms play a game of price competition (Bertrand) with differentiated goods. Firms take the wage rate and final consumption price P and quantity c as given. Firms do recognize their impact on the sectoral quantity z_j via their choices of a_{jk} and p_{jk}.

The technology for producing z_{jt} is

$$z_{jt} = \left[\sum_{k=1}^{2K} \left(x_{jkt} a_{jkt}^{\alpha/(\rho-1)} \right)^{(\rho-1)/\rho} \right]^{\rho/(\rho-1)}. \tag{2}$$

Here a_{jkt} is the "stock available" chosen by manufacturing firm k, satisfying

$$a_{jkt} = a_{jkt-1} + q_{jkt} - x_{jkt-1},$$

and q_{jkt} is production of good k. The idea embodied in equation (2) is that a_{jkt} enhances the value of z_{jt} by, for example, providing a more exact match for some desired characteristics of x_{jkt}. Alternatively, a_{jkt} reduces the cost of converting x_{jkt} into z_{jt}. Of course if $\alpha = 0$ we revert to the case analyzed by Atkeson-Burstein.

Utility-maximization implies that demand for x_{jkt} must satisfy the conditions

$$\frac{\frac{\partial z_{jt}}{\partial x_{jkt}}}{\frac{\partial z_{jt}}{\partial x_{jk't}}} = \frac{p_{jkt}}{p_{jk't}} \ \forall k, k'$$

along with (2). Since

$$\frac{\partial z_{jt}}{\partial x_{jkt}} = \left(\frac{x_{jkt} a_{jkt}^{-\alpha}}{z_{jt}} \right)^{-1/\rho}$$

we get

$$\left(\frac{x_{jkt} a_{jkt}^{-\alpha}}{x_{jk't} a_{jk't}^{-\alpha}} \right)^{-1/\rho} = \frac{p_{jkt}}{p_{jk't}}$$

and it is then straightforward to show that this results in "demand" for x_{jkt}

$$\frac{x_{jkt}}{z_{jt}} = \left(\frac{p_{jkt}}{p_{jt}} \right)^{-\rho} a_{jkt}^{\alpha} \tag{3}$$

where

$$p_{jt} = \left(\sum_k p_{jkt}^{1-\rho} a_{jkt}^{\alpha} \right)^{\frac{1}{1-\rho}} \tag{4}$$

and, consequently, $\Sigma_k p_{jkt} x_{jkt} = p_{jt} z_{jt}$. The sector price index weights the individual prices (inversely) by a_{jkt}^{α}.

A domestic firm k in sector j solves

$$\max_{p_{jkt}, q_{jkt}, a_{jkt}} E_0 \left\{ \sum_{t=0}^{\infty} \beta^t \left(\frac{p_{jkt}}{P_t} x_{jkt} - q_{jkt} \frac{w_t^D}{P_t A_{jkt}} \right) \right\}$$

subject to (3) and

$$a_{jkt} = a_{jk,t-1} + q_{jkt} - x_{jkt-1}$$

where z_{jt} is given by equation (2) and other firms' decisions are taken as given. Because the number of firms is finite, however, each firm does take into account its impact on the sector aggregates p_{jt} and z_{jt}.

Note that since

$$\frac{p_{jt}}{P_t} = \left(\frac{z_{jt}}{c_t}\right)^{-1/\eta}.$$

we can rewrite (3) as

$$\frac{x_{jkt}}{c_t} = \left(\frac{p_{jkt}}{P_t}\right)^{-\rho} \left(\frac{z_{jt}}{c_t}\right)^{1-\rho/\eta} a_{jkt}^{\alpha}$$

Also note that

$$\frac{\partial z_{jt}}{\partial x_{jkt}} \frac{z_{jt}}{x_{jkt}} = \left(\frac{x_{jkt} a_{jkt}^{\alpha/(\rho-1)}}{z_{jt}}\right)^{(\rho-1)/\rho} = \frac{x_{jkt}^{(\rho-1)/\rho} a_{jkt}^{\alpha/\rho}}{\sum_{\ell=1}^{2K} x_{j\ell t}^{(\rho-1)/\rho} a_{j\ell t}^{\alpha/\rho}} = \frac{p_{jkt} x_{jkt}}{p_{jt} z_{jt}} \equiv s_{jkt}.$$

This market share s_{jkt} turns out, as in AB, to be related to the price-elasticity of demand. We show in the Appendix that

$$\epsilon_{jkt} \equiv -\frac{dx_{jkt}}{dp_{jkt}} \frac{p_{jkt}}{x_{jkt}} \tag{5}$$

$$= \frac{1}{1/\rho + (1/\eta - 1/\rho)\, s_{jkt}}. \tag{6}$$

Since $\rho > \eta$, this means that the price elasticity is inversely related to market share.

Let m_t denote the markup of price over replacement cost (the relevant marginal cost with inventories). As usual, optimization over p_{jkt} implies

$$1 + m_t = \frac{\epsilon_{jkt}}{\epsilon_{jkt} - 1}.$$

In the Appendix we show that optimal a_{jkt} satisfies

$$1 = E_t \left\{ \beta \frac{\pi_{t+1}}{\pi_t} \left((1 + m_t) \frac{\alpha}{\rho} \frac{x_{jkt}}{a_{jkt}} + 1 \right) \right\}. \tag{7}$$

where $\pi_t \equiv \frac{w_t^D}{P_t A_{jkt}}$The last condition is very similar to that in Bils and Kahn (2000), and as would be expected, is identical if $\rho = \eta$ (in which case $\epsilon = \rho = (1+m)/m$). In this model, $\epsilon > \rho > \eta$, so the markup is lower then in the $\rho = \eta$ case. But the more important point is that x_{jkt}/a_{jkt} is negatively related to m_t, and hence the inventory-sales ratio is positively related to m_t. Moreover, m_t is not constant, since ϵ_{jkt} varies with market share.

The foreign firm's problem is quite similar, except that it faces a different wage rate and must contend with an exchange rate (which effects revenues). Let e_t denote the exchange rate, where the domestic currency ("dollars") is in the denominator. The foreign firm produces at unit cost π_t^* in its own currency ("yen") and sells in the domestic market for p_{jkt} dollars. Its optimal price satisfies

$$1 + m_t^* = \left(\frac{\epsilon_{jkt}^*}{\epsilon_{jkt}^* - 1} \right)$$

So as a group, foreign firms' optimal choices may differ from domestic firms because of two factors: π^* and e. In addition, all firms differ from one another because of different A's (idiosyncratic productivity).

Suppose the foreign producer's currency appreciates, i.e. e_t declines. Holding ϵ_{jkt} fixed, the firm would raise p_{jkt} proportionally to keep the markup constant. But doing so will cause the firm to lose market share, thereby increasing ϵ_{jkt} and reducing the optimal markup. Consequently, at the new optimum, the firm will increase p_{jkt} by less than the increase in $1/e_t$. Given this, the optimal target ratio of a_{jkt}/x_{jkt} also declines.

We can get some sense of the quantitative changes by looking at steady states, even though presumably movements in e that are unrelated to other variables are transitory. We will consider an exogenous decline in e, holding fixed π, π^* and compute the change in (a_{jk}/x_{jk}) for the foreign firm relative to domestic producers. It is easy to see from (7) that under these assumptions

$$\frac{(a_{jk}/x_{jk})^*}{a_{jk}/x_{jk}} = \frac{ep_{jk}^*}{p_{jk}}$$

so that variation in the inventory–sales ratio is directly related to incomplete pass-through.

More generally, we can condition on the scale variables a and z and solve for the symmetric (if $e = 1$) and asymmetric (across countries) steady states. (Note we still assume symmetry within a country across firms.)

2.4 Numerical Examples

In this section we describe results from a comparison of steady states, starting from $e = 1$. We calibrate several parameters (β, α, ρ) to match certain facts or assumptions, and then consider a range of values for η.

In the automobile industry, the average value of a/x is in the vicinity of 3.5. While we do not observe markups (which is the raison d'etre of this paper), we choose $\rho = 12$ so that they are "reasonable"—in the range of 10 to 20 percent. Finally, we set $\beta = 0.995$, corresponding to a six percent annual discount rate. We set $K = 3$, so that market share is 1/6. Finally, given these choices, we set $\alpha = 0.2$, which gets steady state a/x close to 3.5, and consider $\eta = 2, 3, 4$, and 6.

The top half of Table 1 shows the steady state values of the gross markup $1+m$ and a/x. From the model we know that as η gets closer to ρ, the markup will diminish to $\rho/(\rho - 1)$ or 1.11. The lower markup as η increases also results in a lower average a/x.

The bottom half of the table illustrates the impact of a 2 percent reduction in e, that is, a devaluation of the home currency. The first row shows the impact on the price of imported goods. Note that zero pass-through would result in $ep^*_{jk}/p_{jk} = 0.98$, while complete pass-through would have $ep^*_{jk}/p_{jk} = 1$. We see that for low values of η the pass-through is on the order of 50 percent, midway between the two extremes. Of course the relative price in dollars of foreign-produced goods is $p^*_{jk}/p_{jk} > 1$, so these goods lose market share. For larger values of η, pass-through is more complete, and market share of imports falls by more. Finally, from the previous discussion we know that $ep^*_{jk}/p_{jk} = (a^*/x^*)/(a/x)$ the relative inventory-sales ratio. So we expect movements in that ratio to mirror the extent of incomplete pass-through.

Table 1: Steady State Results				
η	2	3	4	6
$1+m$	1.18	1.14	1.12	1.11
a/x	3.91	3.79	3.73	3.67
Impact of 2% devaluation ($e=0.98$)				
ep^*_{jk}/p_{jk}	0.989	0.992	0.994	0.996
pass-through	45%	60%	70%	80%
s^*_{jk}	0.156	0.152	0.150	0.147

Of course, while exchange rate movements are known to be highly persistent, there is some evidence mean reversion toward purchasing power parity, so these findings should be viewed as impact effects rather than permanent.

3 Data and Estimation Results

3.1 Prices

We first examine proprietary transaction price data obtained from JD Power and Associates. These are monthly average transaction prices of U.S. sales by model year over the period 1999 through 2007. The sales include vehicles manufactured in Japan, Germany, South Korea, and North America. Our goal is to gauge the extent of transaction price responses to changes in exchange rates. We have also collected monthly nominal exchange rate and consumption price deflators for the four countries from the St. Louis Fed's FRED database. We run regressions of the form

$$\log\left(P_{ijt}/P_{1,NA,t}\right) = b_j \log\left(e_{jt}\right) + a_j t + other\ controls + error\ term$$

where $j = GE, JP, SK$, e_{jt} is the real exchange rate for country j relative to the U.S., t is a time trend (to capture apparent trends in real exchange rates during this time period). In some regressions we use e_{jt-1} on the right-hand side rather then e_{jt}The dependent variable is the price at date t of model i, manufactured in country j, relative to the price of a benchmark model built in North America. "Other controls" include month dummies (to allow for seasonal price variation), model, make, and country-of-origin dummies. "Complete" pass-through would correspond to a b coefficient of -1, meaning that the transaction price moves one for one with a change in the exchange rate to keep the price in the manufacturer's currency constant.

An advantage of this dataset is its disaggregated prices, based on actual transactions and at a relatively high (monthly) frequency. It also involves goods that are widely agreed to be "flexible price" goods, in the sense that each transaction is typically negotiated between buyer and seller, so that there are no menu costs or related rigidities. But the specification does not control directly for many factors that might affect pass-through (imported material shares, destination value added, marginal production cost). In particular, we are handicapped by not having data on multiple destinations, though in some specifications we include a domestic automobile price index (available only for Germany and Japan) $\bar{P}_{jt}$ to proxy for local production costs. In general the results (Table 2a) are not qualitatively very sensitive to the different specifications, and indicate very minimal short-run pass-through. The general pattern is no short-run pass-through for Japanese cars (even "reverse" pass-through, meaning a small positive coefficient on the exchange rate), small pass-through on the order of 5 to 15 percent for German cars, and somewhat more (10 to 20 percent) for South Korean cars. Note that the qualitative results for Japan and Germany are similar to the findings in the earlier literature cited above that German cars had more pass-through than Japanese cars. The magnitudes are small, however, perhaps due to the lack of good measures of marginal cost.

Table 2a: Price Regression Results						
Dep. Var	b_{JP}	b_{GE}	b_{SK}	trends	$\bar{P}_{jt}$	e_{t-1}
$\log(P_{ijt})$	0.018	-0.022	-0.119	yes	no	yes
	(0.015)	(0.015)	(0.028)			
$\log(P_{ijt})$	0.037	-0.071	–	yes	yes	yes
	(0.016)	(0.021)				
$\log(P_{ijt})$	0.026	-0.146	-0.183	no	no	no
	(0.012)	(0.010)	(0.015)			
$\log(P_{ijt}/P_{1,NA,t})$	0.043	-0.066	-0.111	yes	no	yes
	(0.019)	(0.025)	(0.038)			
$\log(P_{ijt}/P_{1,NA,t})$	0.060	-0.051	–	yes	yes	yes
	(0.020)	(0.025)				
$\log(P_{ijt}/P_{1,NA,t})$	0.063	-0.159	-0.199	no	no	no
	(0.014)	(0.013)	(0.019)			

Finally, we also considered a specification with a lagged dependent variable, to give some idea of the long-run versus short-run response to the exchange rate would be. The results are shown in Table 2b. They show substantial inertia in the transactions price (though in this specification we constrain the coefficient on the lagged price term to be the same for all three countries), but even so, the long-run adjustment is small for all three countries of origin, though Germany's is not far below fifty percent.

Table 2b: Dynamic Passthrough

Dep. Var	b_{JP}	b_{GE}	b_{SK}	$\log(P_{ij,t-1})$	trends	$\bar{P}_{jt}$	e_{t-1}
: $\log(P_{ijt})$	-0.0007	-0.057	-0.003	0.852	no	no	yes
	(0.0005)	(0.007)	(0.028)	(0.004)			

To summarize, we find very limited pass-through of exchange rates to prices in these data, and some heterogeneity by country of origin along the lines of earlier researchers. No pass-through at all (or even a bit of reverse pass-through) for Japan, and modest (on the order of 10 percent for Germany and South Korea. We present limited evidence that long-run pass-through may be substantially larger than short-run pass-through. These results are at least suggestive of substantial markup variation, as envisioned in the model and as able to motivate the empirical work in the next section on inventory responses. Nonetheless, they also may reflect the fact that we do not have measures of marginal cost, which may be correlated with movements in exchange rates. If so, markups may not be moving as much as suggested by the lack of price responses. Previous estimates of pass-through in the automobile industry (e.g. Gagnon and Knetter, 1995) have found it to be in the vicinity of 50 percent, depending on the vehicle type.

3.2 Quantities

We have collected monthly data on U.S. inventories and sales for automobiles from four countries of origin: Germany, Japan, South Korea, and the U.S. itself. We also have (confidential) data on transactions prices. To match the latter, we have assembled the data to cover the period from January 1999 to November 2007. While the data are available at the level of individual models, because of the entry and exit of models, and problems associated with models that have very low sales in given months, we have aggregated the data to the level of total U.S. sales and inventories by country of origin.

In principle we can estimate the parameters of the model, as we have done in another paper (Kahn and Copeland, 2011). While many of the key variables in the model such as A and x are not directly measured (or at least not well enough for the purposes of this paper) because they include the stock of used vehicles, we can nonetheless estimate the model based on the behavior of observable counterparts I_t and s_t. This paper's more narrow focus and the structure of the data lead us to adopt a less parametric approach.

Figure 3 shows the actual a/s ratios by country of origin, along with the the relative ratios. The a/s ratios appear to comove fairly closely, though a lot of that may be seasonal in nature. The relative ratios would largely eliminate common seasonal movements but nonetheless also exhibit some comovement

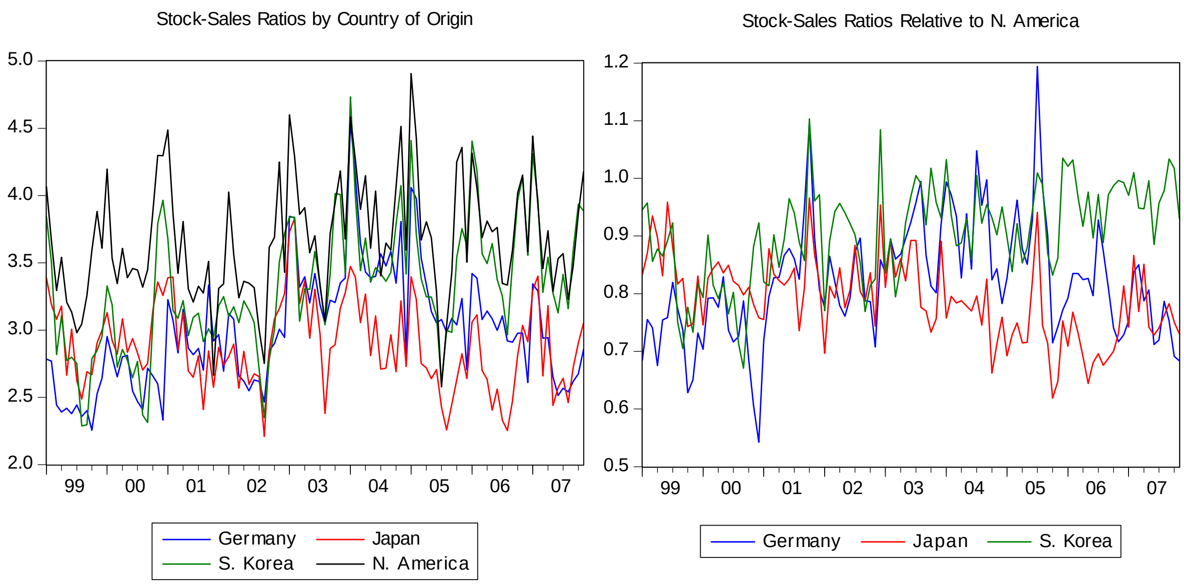

Figure 3: Stock-Sales Ratios

Figure 4 shows our real exchange rate series. The nominal exchange rate series, not surprisingly, look very similar, albeit with slightly different trends.

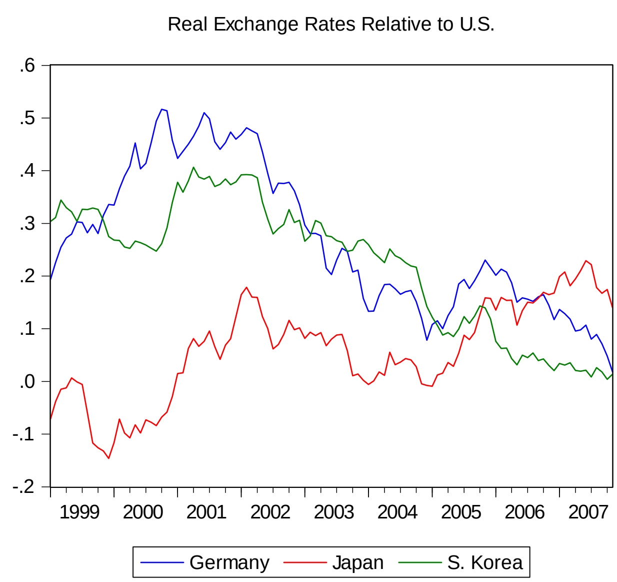

Figure 4: Real Exchange Rates

Given that in the short samples there are slight trends in the dependent variable (perhaps due to composition effects), the presence of trends in the real exchange rate series is obviously problematic for the estimation, as the focus here is on higher frequency movements. Since explaining the trends is outside the scope of this paper, we will simply include separate time trends in our regressions.

We use a difference-in-difference style specification, looking at the impact of real exchange rate movements on relative inventory-sales ratios. That is, let RAS_{it} denote the a/s ratio for automobiles originating in country i relative to that for automobiles originating in the U.S., and let REX_{it} denote the real exchange rate $e_t = E_t P_t / P_{it}$, where E_t is the nominal rate in foreign currency per dollar, P_t a U.S. price index, and P_{it} a price index for country i. We estimate equations of the form

$$\log(RAS_{it}) = \alpha_i + b_i \log(REX_{it-k}) + c_i t + u_{it}$$

for various values of k or

$$\log(RAS_{it}) = \alpha_i + b_i \log(REX_{it}) + c_i t + u_{it}$$

where we instrument for $\log(REX_{it})$ using lagged values. We allow for fixed effects because markups or vehicle characteristics may differ systematically by country of origin.

The regression results for various specifications are shown in Table 3. All results include fixed effects for country of origin and separate trends. Otherwise, we consider various lags of REX (where $k = 0$ implies instrumental variables), to allow for the unknown lag between the observation of exchange rate movements on the one hand, and pricing and shipment decisions get made. We also test the constraint that the coefficients on $\log(REX)$ are the same and fail to reject it at the 5 percent significance level.

Table 3: Regression Results

k	b	b_{GE}	b_{JP}	b_{SK}	R^2
1	0.142	–	–	–	0.383
	(0.072)				
1	–	−0.008	0.267	0.345	0.393
		(0.098)	(0.148)	(0.144)	
0	0.151	–	–	–	0.386
	(0.076)				
2	0.167	–	–	–	0.386
	(0.070)				
3	0.190	–	–	–	0.390
	(0.069)				

Thus the results show a significant positive impact of an appreciation of the dollar on inventory-sales ratios of imported vehicles, consistent with the idea that the appreciation results in increased markups. The effect gets slightly stronger and more significant with longer lags.

Note that using the real exchange rate at least controls for changes in nominal production costs due to inflation or deflation. For example, if the Yen appreciates relative to the dollar because of deflation in Japan, presumably nominal marginal cost declines at the rate of deflation as well, so there would be no real impact on markups from leaving the U.S. price unchanged. In any case, regression results using the nominal exchange rates were very similar to those in Table 2.

A b coefficient of 0.15 means that, for example, a 10 percent real appreciation of the dollar results in a 1.5 percent increase in a/s. That is qualitatively consistent with the model, but indicative of more pass-through—essentially 85 percent, though less for Japan and South Korea, more for Germany—than we were able to find in the price data, and somewhat more than other researchers have found. On the other hand, the estimates for

Japan and South Korea are not significantly different from 0.5, consistent with Gagnon and Knetter's (1995) estimates of pass-through cited earlier, and we again see the pattern of more pass-through Germany than Japan. Thus it is likely that there are movements in marginal cost, or quantitatively important local value added, that helps to account for the lack of price responses to exchange rates, but that significant incomplete pass-through remains, at least for Japanese and Korean models.

4 Conclusions

This paper finds evidence that exchange rate movements are associated with movements in markups by looking at the responses of inventory-sales ratios. The so-called stockout-avoidance model of inventories implies that inventory-sales ratios are positively related to markups, and previous research has suggested that at least at business cycle frequencies, changing markups are the primary factor influencing inventory-sales ratios. Using data on U.S. automobile sales and inventories by country of origin, we find strong evidence that exchange rate movements affect inventory-sales ratios, consistent with changing markups. We also provide a model of the joint determination of prices, markups, production, and inventories, steady state analysis of which provides qualitative and quantitative support for the empirical findings. In particular, the responses of inventory-sales ratios are broadly consistent with findings of pass-through rates of 50 to 75 percent, which are somewhat higher than in the literature, but with a similar pattern across countries of origin.

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