Pass-through of Exchange Rates

and Competition Between Mexico and China

by

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Abstract

This paper studies how a rise in China's share of U.S. imports could lower pass-through of exchange rates to U.S. import prices. We develop a theoretical model with variable markups showing that the presence of exports from a country with a fixed exchange rate could alter the competitive environment in the U.S. market. In particular, this encourages exporters from other countries to lower markups in response to a U.S. depreciation, thereby moderating the pass-through to import prices. Free entry is found to further moderate the pass-through, in that a U.S. depreciation encourages entry of exporters whose costs are shielded by the fixed exchange rate, which further intensifies the competitive pressure on other exporters. The model predicts that certain conditions are necessary to facilitate this 'China explanation' for falling pass-through, including a 'North America bias' in U.S. preferences. The model also produces a log-linear structural equation for pass-through regressions indicating how to include the China share. Panel regressions over 1993–1999 support the prediction that a high China share in imports lowers pass-through to U.S. import prices.

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1. Introduction

Exchange rate movements have several potentially important implications for the domestic macroeconomy, including inflation variability, monetary policy effectiveness, and current account adjustment. But the importance of these implications depends in part on how much of the exchange rate movements are passed through to changes in import prices. A number of recent papers have found evidence indicating a decline in exchange rate pass-through to import prices in the U.S. While there appears to be agreement within the literature surveyed in Goldberg and Knetter (1997) that the pass through in the 1980s was around 0.5, several papers find much lower estimates for recent years. Marazzi *et al* (2005) estimate that the pass-through coefficient for U.S. imports has declined gradually from 0.5 to around 0.2, and similar results are found in Olivei (2002) and Gust *et al* (2006). It is less clear how this decline in pass through applies to other countries, and how it applies to prices at the consumer level.[1]

Several potential explanations have been proposed for how pass-through might decline. Taylor (2000) suggested that and environment of lower inflation might discourage firms from adjusting import prices. Campa and Goldberg (2005) suggest and find evidence in support of the idea that the composition of imports has shifted toward goods that are less sensitive to exchange rates, that is, away from energy and toward manufactures. Others have suggested that the competitive environment for imports has changed. Included in this group are Gust *et al* (2006), which propose that increased trade integration has made exports more responsive to the prices of their competitors. They develop a dynamic model with endogenous entry decisions and markups

[1] Ihrig et al, (2006) document a fall in pass-through in other G-7 countries, and Marazzi *et al* (2005) for Japan and less strongly for Germany. Campa and Goldberg (2005) find that the decline in pass through is statistically significant in only 4 of the 23 OECD countries they study, and in particular for the U.S. they do not find a significant decline. Campa and Goldberg (2006) find evidence that the pass through to retail prices may have increased over the past decade, even in cases where import prices at the dock might be experiencing falling pass-through.

that respond endogenously to entry. Also in this category would be the proposition by Marazzi *et al* (2005) that the increased role of China as a source of U.S. imports has lowered pass-through, both due to the direct effect of its stable exchange rate against the dollar, and by inducing a competitive response in the exporters of other countries.

Evidence varies regarding which of these types of channels is relevant. Campa and Goldberg (2005) find in their multi-country study that pass-through tends to be stable within industry categories, but that the change in composition can account for much of any overall fall in aggregate pass-through. While the evidence in Marazzi *et al* (2005) agrees that a falling share of oil imports plays a role, nonetheless, evidence is found that pass-through has fallen across a wide range of goods. Further, they also find a correlation between industries that experienced a fall in pass-through and those that experienced the strongest increase in Chinese imports.

The primary purpose of this paper is to provide a theoretical framework for exploring how the rise of China as a supplier to the U.S. could have altered the competitive environment for U.S. imports, and thereby generate time-variation in pass-through. The theory draws upon recent developments in trade theory to shed light on this issue, including endogenous entry and markup decisions by firms. The explanation we develop is similar in spirit to that in Dornbusch (1987), in that the market share of the fixed-exchange rate country in our model affects pass-through in the same manner as the market share of domestic firms does in Dornbusch's model.[2] Gust *et al* (2006) also draws similar inspiration from trade literature in its study of pass-through. We differ from both of these papers in our use of translog preferences to generate time-variation in markups and pass-through. In fact, we regard the extension of translog expenditure function

[2] Dornbusch (1987) was the first to show how market share influences the degree of pass-through, using a model of Cournot competition. Our model instead uses monopolistic competition, but allows market share to affects pass-through by using a utility form that is not CES. Note that our translog expenditure form is not a special case of the demand structures studied by Dornbusch.

found in our paper's several propositions to be a theoretical contribution that could be of use in studying a range of other issues. Finally, we also note that the lessons developed in our model are not restricted to China, but are relevant for understanding the effects of changing market share more broadly of all trading partners with fixed exchange rates.

We consider a three-country model with the United States, Mexico and China. We eliminate any role for U.S. competing firms to affect the pass-though of exchange rates by supposing that the United States only sells a homogeneous exported good. Our focus is on the interplay of Mexican and Chinese exporters to the U.S., both of whom sell a differentiated good. The peso is treated as floating, of course, while the yuan (or renminbi) is fixed. In section 2 we give a basic outline of the monetary model, which features wages that are fixed in the short-run. Beyond the simple distinction between the short-run (with fixed wages) and the long-run (with flexible wages), we do not introduce any further dynamics into the model.

In section 3, we analyze the pricing decisions of Mexican and Chinese exporters to the U.S. market. We use a translog expenditure function to model U.S. demand. As previously analyzed by Bergin and Feenstra (2000, 2001), this expenditure function allows for endogenous markups that vary with the exchange rate, thereby leading to incomplete pass-through. In addition, this expenditure function can be used even when the number of firms varies due to free entry under monopolistic competition (Bergin and Feenstra, 2006). In that case, it is necessary to solve for the reservation prices of goods that are not available (i.e. prices when demand is zero). In this paper we extend the results of Feenstra (2003) in solving for reservation prices, obtaining a reduced-form expenditure function that allows for a taste bias in favor of some goods. In particular, we shall suppose that U.S. buyers have a taste bias in favor of Mexican goods, due to its proximity, common border and NAFTA.

In section 4, we analyze the pass-through of exchange rates treating the number of firms as fixed. Competition from China diminishes the pass-through of the peso exchange rate to the price of U.S. imports from Mexico. We show that when we aggregate up to multilateral import prices and exchange rates – by aggregating over Mexico and China – then pass-through is still incomplete (even though we have assumed no competing U.S. firms). The incomplete pass-through is related to our assumed taste bias in favor of Mexico, and becomes more pronounced as the number of competing Chinese exporters grows. So competition between China and Mexico – in the presence of a U.S. taste bias – results in incomplete pass-through.

In section 5, we examine the empirical implication using disaggregate U.S. import data from the 1990s. Like Marazzi *et al* (2005, pp. 21-23), we test whether having more competition from China results in lower pass-through coefficients at an industry level, and find support for this hypothesis.[3] Section 6 extends the model by allowing for the free entry of firms, which can occur in response to monetary and exchange rates shocks. In that case we simulate the model, and find a further reason for incomplete pass-through: a monetary expansion in the U.S. leads to greater entry of firms in China, creating an extra competitive effect that leads to lower import prices. So the free entry of firms lowers the pass-through of the dollar further. Conclusions are provided in section 7, and the proofs of Proposition are gathered in the Appendix.

2. Countries, Commodities and Currencies

There are three countries: Mexico (denoted by x) , China (denoted y for yuan), and the

[3] Our empirical investigation differs from Marazzi *et al* (2005) in several respects. Foremost, we develop a theoretical justification for including the China share as a structural component of a pass-through regression. In terms of estimation differences, we run a pooled panel pass-through regression across industries and time, rather than running pass through regressions for two sub-samples of time and comparing changes in pass through to changes in China share across industries. Our data also differ, in that exchange rate and tariff measures (from Feenstra *et al,* 2007) are constructed to be consistent with the theoretical price index we use.

Untied States (denoted by z). The U.S. produces the z good, which can be thought of as an homogeneous good (e.g. agriculture), and exports it to both Mexico and China. One unit of labor produces one unit of the z good, so the price of the U.S. good equals the wage, w_z. China and Mexico produce a differentiated good that is sold back to the United States. Their prices are p_x (in pesos) and p_y (in yuan), which are common across all the varieties sold by each country. The \$/peso exchange rate is e_x, so the \$ price of imports from Mexico is $e_x p_x$, and the \$/yuan exchange rate is $\bar{e}_y$, so the \$ price of imports from China is $\bar{e}_y p_y$. Note that $\bar{e}_y$ is a fixed exchange rate, whereas e_x is flexible.

We model the cash-in-advance constraint as in Bacchetta and van Wincoop (2000). Each government provides a money transfer of M_i, i = x, y, z to home residents at the beginning of the period, and imposes an identical tax at the end of the period after all transactions are made. Money will then serve as a unit of account in each country, but does not have any distortionary effect by itself. We presume that expenditure in each country equals the money supply from the cash-in-advance constraints. Under balanced trade, expenditure in turn equals the value of output. With labor as the only factor of production, and with zero profits (due to free entry, discussed in section 6), the money supply in each country therefore equals wage income:

$$M_i = w_i L_i, \quad i = x, y, z. \tag{1}$$

Each country spends a fraction β of wage income on its own, homogeneous good. In the United States, the remaining fraction (1–β) of expenditure is spent on the differentiated good, imported from either China or Mexico. For Mexico and China, the remaining (1–β) of income is spent on the U.S. homogeneous good. For example, Mexican spending on the U.S. good is

$(1-\beta)\overline{w}_x L_x = (1-\beta)M_x$. The peso price of the U.S. good equals the \$ price w_z (since one unit of labor produces one unit of output) divided by the peso exchange rate e_x :

$$\text{Mexican demand for U.S. good} = \frac{(1-\beta)M_x}{w_z / e_x} = e_x \frac{(1-\beta)M_x}{w_z}.$$

Likewise, Chinese demand is:

$$\text{Chinese demand for U.S. good} = \frac{(1-\beta)M_y}{w_z / \overline{e}_y} = \overline{e}_y \frac{(1-\beta)M_y}{w_z},$$

where the yuan exchange rate, $\overline{e}_y$, is fixed. Finally, U.S. demand for its own good is:

$$\text{U.S. demand for U.S. good} = \frac{\beta M_z}{w_z}.$$

Summing all the demands we get the U.S. equilibrium condition,

$$e_x \frac{(1-\beta)M_x}{w_z} + \overline{e}_y \frac{(1-\beta)M_y}{w_z} + \frac{\beta M_z}{w_z} = L_z. \tag{2}$$

While (2) has been derived as the goods market equilibrium condition for the U.S., it can also be interpreted as asset market equilibrium condition for dollars. Multiplying both sides of the equation by w_z, the right of (2) is the U.S. money supply M_z. On the left, the first term is the U.S. dollars that Mexican consumers would need to purchase from the U.S.; the second term is the dollars that Chinese consumers would need; and the third term is the dollars that U.S. consumers need to purchase their local good. So under the assumption that consumers use the currency of the selling country, (2) can be interpreted as the asset market equilibrium condition for dollars.

We assume that wages are fixed at the beginning of the period, and that labor supply is demand determined. We can model the specifics of the wage-setting mechanism as in Obstfeld and Rogoff (2000), which leads to a nominal wage $\overline{w}_i$ that is fixed in the short-run. [4]

Determining the Mexican exchange rate

In the short-run wages are fixed, so using (1) we write (2) as:

$$e_x \frac{(1-\beta)M_x}{\overline{w}_z} + \overline{e}_y \frac{(1-\beta)M_c}{\overline{w}_z} + \frac{\beta M_z}{\overline{w}_z} = L_z = \frac{M_z}{\overline{w}_z}$$

$$\Rightarrow \; e_x M_x + \overline{e}_y M_y = M_z . \tag{3}$$

A 1% increase in the U.S. money supply can be accommodated by a 1% increase in e_x (a depreciation of the dollar) and a 1% increase in the Chinese money supply (to keep $\overline{e}_y$ fixed). In the background, there is 1% more of the U.S. good produced, which is consumed both in the U.S. (due to increased expenditure), in China (due to increased expenditure) and in Mexico (due to an appreciation of the peso and lower prices there).

Notice that if China does not accommodate the U.S. monetary expansion by increasing its money supply in the same proportion, then the peso will appreciate by a different amount. In general, given some assumption on the responsiveness of M_y to M_z, then (3) is enough to determine the peso exchange e_x in the short-run. In sections 3 and 4, we will not need to make

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[4] We can follow Obstfeld and Rogoff (2000) in specifying expected utility for agent h as $E[\ln C(h) - (a/\varepsilon)L(h)^{\varepsilon}]$, where C is the Cobb-Douglas consumption index over home and foreign goods with home share β described in the text above. Due to the fact that the consumption sub-index over foreign varieties for the U.S. is only implicitly defined under our translog preferences to follow, we apply the derivation of Obstfeld and Rogoff (2000) only for the cases of Mexico and China. Fortunately, solving for pass-through in our model requires us to find wage levels and hence costs for these two countries only (and we omit the country subscript). Consumers choose consumption and their own wage w(h) to maximize utility subject to their budget constraint and the demand for labor type h, $L(h) = [w(h)/w]^{-\phi} L$, where w and L are CES indexes over the wages w(h) and labor demands L(h). Then it can be shown that optimal wage setting by each agent leads to the aggregate wage $\overline{w} = -[\phi/(\phi-1)]E[LU'_L]/E[LU'_C/P]$, where P is the price index of consumption goods. For suitable choices of the various parameters ε, a, and ϕ>1, conditional on the means, variances , means and covariances of consumption, labor, and price, we can obtain any desired value for the optimal preset wage.

any particular assumption on the responsiveness of M_y to M_z, and hence on the movement in the peso rate e_x. In section 6, however, we will use the asset market equilibrium condition for yuan to show how the Chinese money supply M_y changes in response to the U.S. money supply M_z, and therefore solve the equilibrium change in the peso rate e_x.

3. Translog Expenditure Function

A fraction (1-β) of expenditure in the U.S. is spent on imported differentiated goods, produced by Mexico and China. Since the work of Dixit and Stiglitz (1977), a common choice for the utility function defined over the differentiated products has been the constant elasticity of substitution (CES) form. Despite its tractability, this functional form has serious drawbacks for the analysis of firm's pricing. Since optimal prices are a constant markup over marginal costs, there is no strategic interaction between the firms.

This special feature of the CES need not carry over to other choices of the sub-utility function. We will consider a sub-utility function defined by the dual expenditure function which is assumed to have a translog form. That is, given nominal expenditure E, the sub-utility from consumption of the differentiated products 1,…,N is u = E/e(p), where the unit-expenditure function e(p) is defined by:

$$\ln e(p) = \alpha_0 + \sum_{i=1}^{\tilde{N}} \alpha_i \ln p_i + \tfrac{1}{2} \sum_{i=1}^{\tilde{N}} \sum_{j=1}^{\tilde{N}} \gamma_{ij} \ln p_i \ln p_j \,, \tag{4}$$

with $\gamma_{ij} = \gamma_{ji}$. The parameter $\tilde{N}$ is the maximum number of possible products, but many of these might not be produced: the prices used for products not available should equal their reservation prices (where demand is zero). Notice that in the CES case the reservation prices are infinite, so these prices drop out of the CES expenditure function (where the infinite prices are raised to a negative power). But in the translog case we need to explicitly solve for the reservation prices.

In order for the translog expenditure function to be homogeneous of degree one, we need to impose the conditions,

$$\sum_{i=1}^{\tilde{N}} \alpha_i = 1, \text{ and } \sum_{i=1}^{\tilde{N}} \gamma_{ij} = 0. \tag{5}$$

We will further require that all goods enter "symmetrically" in the γ_{ij} coefficients, and impose that additional restrictions that:

$$\gamma_{ii} = -\gamma\left(\frac{\tilde{N}-1}{\tilde{N}}\right), \text{ and } \gamma_{ij} = \frac{\gamma}{\tilde{N}} \text{ for } i \neq j, \text{ with } i, j = 1,\ldots,\tilde{N}. \tag{6}$$

Notice that we do not restrict the α_i coefficients beyond the restriction in (5). That is in contrast to Feenstra (2003), who added the further restriction that $\alpha_i = 1/\tilde{N}$.

We now show how the symmetry restrictions in (6) allow us to solve for the reservation prices for goods not available, substitute these back into the expenditure function in (4), and obtain a reduced-form expenditure function that is very convenient to work with. In particular, this reduced-form expenditure function remains valid even as the number of available products – which we denote by N – varies. The following Proposition generalizes the result in Feenstra (2003), by allowing for α_i terms that are not symmetric:

Proposition 1

Suppose that the symmetry restriction (6), with $\gamma > 0$, are imposed on the expenditure function (4). In addition, suppose that only the goods i=1,…,N are available, so that the reservation prices $\tilde{p}_j$ for j=N+1,…, $\tilde{N}$ are used. Then the expenditure function becomes:

$$\ln e(p) = a_0 + \sum_{i=1}^{N} a_i \ln p_i + \tfrac{1}{2}\sum_{i=1}^{N}\sum_{j=1}^{N} c_{ij} \ln p_i \ln p_j \,. \tag{7}$$

where,

$$c_{ii} = -\gamma(N-1)/N, \text{ and } c_{ij} = \gamma / N \text{ for } i \neq j \text{ with } i, j = 1,\ldots,N, \tag{8}$$

$$a_i = \alpha_i + \tfrac{1}{N}\left(1 - \sum\nolimits_{i=1}^{N} \alpha_i\right), \quad \text{for } i = 1,\ldots,N, \tag{9}$$

$$a_0 = \alpha_0 + \left(\frac{1}{2\gamma}\right)\left\{\sum\nolimits_{i=N+1}^{\tilde{N}} \alpha_i^2 + \left(\frac{1}{N}\right)\left(\sum\nolimits_{i=N+1}^{\tilde{N}} \alpha_i\right)^2\right\}, \tag{10}$$

Notice that the expenditure function in (7) looks like a conventional translog function, but now defined over the *available* goods i=1,…,N, while the symmetry restrictions in (6) continue to hold on the coefficients c_{ij}. To interpret (9), it implies each of the coefficients α_i is increased by the same amount to ensure that the coefficients a_i sum to unity over i=1,…,N. The term a_0 in (10) incorporates the coefficients α_i of the unavailable products. If the number of available products N rises, then a_0 falls, indicating a welfare gain from increasing the number of products.

With this Proposition, we can work with the expenditure function in (7), knowing that the reservation prices for unavailable goods are being solved for in the background. We can differentiate the unit-expenditure function to obtain the expenditure shares,

$$s_i = a_i + \sum_{j=1}^{N} c_{ij} p_j \,. \tag{11}$$

The parameters c_{ij} in (11) are symmetric over goods sold by Mexico and China, indicating equal substitution between these goods. We shall put further structure on the taste a_i parameters by supposing that the United States has a bias towards goods made in Mexico, due to its proximity, common border and NAFTA. That is, we shall assume a_x for any Mexican good exceeds a_y for any variety from China. From (9) we see that the assumption $a_x > a_y$ is equivalent to $\alpha_x > \alpha_y$, but that the a_x and a_y parameters also depend on the number of available goods N.

For products from Mexico, the U.S. dollar price is $p_i = p_x e_x$, and for products from China the U.S. dollar price is $p_i = p_y \bar{e}_y$. We assume that these prices are common across the firms from each country (due to identical costs), and denoting the number of Mexican varieties by N_x and the number of Chinese varieties by N_y, with $N_x + N_y = N$. Then using (8), the share equations are simplified as:

$$s_x = a_x - \frac{\gamma N_y}{N}\left[\ln(e_x p_x) - \ln(\bar{e}_y p_y)\right], \tag{12a}$$

$$s_y = a_y - \frac{\gamma N_x}{N}\left[\ln(\bar{e}_y p_y) - \ln(e_x p_x)\right]. \tag{12b}$$

Using these demand equations, we next solve for the firm's optimal prices, and then the pass-through of the exchange rate.

4. Pass-though of Exchange Rates with Fixed Number of Firms

From the perspective of a firm selling one of the differentiated products, the elasticity of demand for the input is computed from (11) as $\eta_i = 1 - \dfrac{\partial \ln s_i}{\partial \ln p_i} = 1 - \dfrac{c_{ii}}{s_i} = 1 + \dfrac{\gamma(N-1)}{s_i N}$, $\gamma > 0$.

We will ignore uncertainty about the exchange rate, and suppose that firms set prices (in their own currencies) after knowing the exchange rate. One unit of production uses one unit of labor in either country. Then each firm will optimally choose its price as,

$$p_i = w_i\left(\frac{\eta_i}{\eta_i - 1}\right) = w_i\left(1 + \frac{s_i N}{\gamma(N-1)}\right). \tag{13}$$

The expenditure share can be substituted from (12) to obtain an expression for the optimal price in (13), in terms of its marginal cost and the prices of its competitors. However, this expression is nonlinear (involving the level of prices on the left, and the log of prices on the right), and cannot be solved explicitly for the optimal price. So instead, we will consider taking an approximation to (13) that will allow us to obtain a simple solution for the price. Taking logs of both sides of (13) and using $\ln[1 + s_i N / \gamma(N-1)] \approx s_i N / \gamma(N-1)$ which is valid for s_i small, we obtain:

$$\ln p_x \approx \ln w_x + \frac{a_x N}{\gamma(N-1)} - \frac{N_y}{(N-1)}\left[\ln(e_x p_x) - \ln(\bar{e}_y p_y)\right], \tag{14a}$$

$$\ln p_y \approx \ln w_y + \frac{a_y N}{\gamma(N-1)} - \frac{N_x}{(N-1)}\left[\ln(\bar{e}_y p_y) - \ln(e_x p_x)\right]. \tag{14b}$$

These are two equations to solve for the two prices – of Mexican and Chinese goods – depending on the peso exchange rate (since the yuan exchange rate is fixed). Expressing the prices on the left of (14) in dollars, we can re-write this system in matrix form as:

$$\begin{bmatrix} 1 + \frac{N_y}{(N-1)} & -\frac{N_y}{(N-1)} \\ -\frac{N_x}{(N-1)} & 1 + \frac{N_x}{(N-1)} \end{bmatrix} \begin{bmatrix} \ln(e_x p_x) \\ \ln(\bar{e}_y p_y) \end{bmatrix} = \begin{bmatrix} \ln(e_x w_x) + \frac{a_x N}{\gamma(N-1)} \\ \ln(\bar{e}_y w_y) + \frac{a_y N}{\gamma(N-1)} \end{bmatrix}.$$

The determinant of the matrix above is: $\Delta \equiv \left[1 + \frac{N_x}{N-1}\right]\left[1 + \frac{N_y}{N-1}\right] - \left(\frac{N_x}{N-1}\right)\left(\frac{N_y}{N-1}\right) = \left(\frac{2N-1}{N-1}\right)$.

It follows that we can solve for the \$ import prices by inverting the above matrix, and after some simplification using (9) we obtain:

$$\ln(e_x p_x) = \frac{1}{\gamma(N-1)} + \ln(e_x w_x) + \frac{N_y}{(2N-1)}\frac{A}{\gamma}, \tag{15a}$$

and

$$\ln(\bar{e}_y p_y) = \frac{1}{\gamma(N-1)} + \ln(\bar{e}_y w_y) - \frac{N_x}{(2N-1)}\frac{A}{\gamma}, \tag{15b}$$

where, $$A \equiv [(\alpha_x - \alpha_y) - \gamma[\ln(e_x w_x) - \ln(\bar{e}_y w_y)].\tag{15c}$$

Holding wages fixed, we solve for the effect of a dollar depreciation – as reflected in the peso rate – on the \$ prices of Mexican and Chinese goods:

$$\frac{d\ln(e_x p_x)}{d\ln e_x} = 1 - \frac{N_y}{(2N-1)} > 0,\tag{16a}$$

and, $$\frac{d\ln(\bar{e}_y p_y)}{d\ln e_x} = \frac{N_x}{(2N-1)} > 0.\tag{16b}$$

We see that the dollar depreciation will raise the \$ price of Mexican goods, but by an amount *less than unity.* The greater is the number of Chinese varieties – reflecting more competition from China – the smaller is the pass-through coefficient in (16a). The rise in the \$ price of Mexican goods will also induce a rise in the \$ price of Chinese goods in (16b), but by an amount that becomes small as the number of Mexican varieties shrinks.

Pass-through of the multilateral exchange rate

The above equations (16) show the pass-through of the peso rate to dollar prices of Mexican and Chinese goods. In practice, pass-through is often measured using multilateral (aggregate) import prices and exchange rates. To achieve that here, define and import price and multilateral exchange rate:

$$\ln P_m \equiv (s_x N_x)\ln(e_x p_x) + (s_y N_y)\ln(\bar{e}_y p_y),\tag{17a}$$

$$\ln E_m \equiv (s_x N_x)\ln(e_x) + (s_y N_y)\ln(\bar{e}_y).\tag{17b}$$

The weights using in these aggregates reflect the import shares of *each firm* selling from Mexico and China, s_x and s_y, respectively, times the number of firms, N_x and N_y. So $s_x N_x$ is the share of U.S. imports coming from Mexico, and $s_y N_y$ is the share of imports coming from China, with

$(s_x N_x + s_y N_y) = 1$. We shall treat these shares as constant when differentiating the aggregates (as they would be in any price index), obtaining:

$$d\ln P_m = (s_x N_x) d\ln(e_x p_x) + (s_y N_y) d\ln(\bar{e}_y p_y)\,, \tag{18a}$$

$$d\ln E_m = (s_x N_x) d\ln(e_x), \tag{18b}$$

where in (18b) we make use of the fact that the yuan exchange rate is fixed. Then multiplying (16a) by $s_x N_x$ and (16b) by $s_y N_y$ and summing these equations, we obtain:

$$\frac{d\ln P_m}{d\ln E_m} = 1 - \frac{N_y}{(2N-1)}\left(\frac{s_x - s_y}{s_x}\right) < 1 \quad \text{iff} \quad (s_x - s_y) > 0. \tag{19}$$

Thus, pass-through of the multilateral exchange rate is incomplete provided that the per-firm (or per-product) share of Mexico exports to the U.S. exceeds that for China, $(s_x - s_y) > 0$. The intuition for this result is as follows. Equation (16a) shows that Mexican pass-through is lowered by a high number of competing Chinese firms. But for Chinese prices, equation (16b) shows that there is some price rise even though there is no movement in China's bilateral exchange rate. As a result, when computing the multilateral exchange rate and multilateral pass through as averages over the two countries, a high weight on China tends to raise rather than lower pass-through in (19). So pass through is lowered by having a large number of Chinese firms while at the same time not having a large overall China share; this combination is possible only if the per-firm share for Chinese firms is small. In short, the main lesson is that pass-through is reduced by having a large number of Chinese firms active in the U.S. market, rather than by a large Chinese market share per se.

The condition of a smaller per-firm share for Chinese firms is likely to hold given our earlier assumption that the United States has a taste bias for Mexican goods. Using (9), (12), and (15) we solve for the shares:

$$s_x = \frac{1}{N} + \frac{N_y}{N}\left(\frac{N-1}{2N-1}\right)A \text{, and } s_y = \frac{1}{N} - \frac{N_x}{N}\left(\frac{N-1}{2N-1}\right)A \tag{20}$$

where $A \equiv [(\alpha_x - \alpha_y) - \gamma[\ln(e_x w_x) - \ln(\bar{e}_y w_y)]$, as in (15c). Provided that A > 0, then $(s_x - s_y) > 0$ and there is incomplete pass-through of the multilateral exchange rate:

<u>Proposition 2</u>

Provided that A > 0, then multilateral pass-through in (19) is less than unity and is decreasing in N_y. If 0 < A < 1, then pass-through falls for any increase in N_y satisfying $d\ln N_y > d\ln N \geq 0$.

We see that provided the taste bias in favor of Mexico exceeds the wage differences between the two countries, so that A > 0, then pass-through is incomplete. It is easy to show that pass-through declines as the number of varieties coming from China grows, holding N fixed. We further show in the Appendix that any increase in N_y exceeding the percentage increase in N, $d\ln N_y > d\ln N \geq 0$, will lower pass-through, using the mild additional restriction that A < 1. The inequality $d\ln N_y > d\ln N \geq 0$ is satisfied, for example, by an increase in N_y holding N_x fixed. So greater competition from China lowers the extent of pass-through.

It is worth reminding the reader that we have not considered competing U.S. firms in our model, thereby ruling out the most obvious reason for incomplete pass-through, i.e. domestic competition. What we have found is that the competition between Mexico and China, in the presence of a U.S. taste bias towards Mexico – what we shall call a 'North America bias' – plays much the same role as would domestic competition in dampening exchange rate pass-through. Stately less formally, we are suggesting that the integration of the North American market through NAFTA, combined with the rise of China as a major trading partner for the U.S., are a potential explanation for the declining pass-though during the 1990s that has been observed for the United States.

Estimating Equation

Using (15), (17) and (20), the import price index P_m is solved as:

$$\ln P_m = \frac{1}{\gamma(N-1)} + \ln \tilde{E}_m - B(s_y N_y)[\ln \tilde{E}_m - \ln(\bar{e}_y w_y)] + \left(\frac{\alpha_x - \alpha_y}{\gamma}\right) B(s_y N_y)(s_x N_x), \quad \text{(21a)}$$

where: $$\ln \tilde{E}_m \equiv [(s_x N_x)\ln(e_x w_x) + (s_y N_y)\ln(\bar{e}_y w_y)], \quad \text{(21b)}$$

and, $$B \equiv \frac{(s_x - s_y)}{s_x s_y (2N-1)} > 0 \text{ provided that } A > 0. \quad \text{(21c)}$$

Equation (21a) shows that the translog expenditure function leads to a log-linear equation for the import price. The first term on the right of (21a), $1/\gamma(N-1)$, reflects the monopoly markup. The second term on the right, $\ln \tilde{E}_m$, equals the weighted exchange rate adjusted for wages in the countries, or what we call *multilateral labor costs.* This term also appears in the third term on the right of (21), but now it is specified as the *difference between* the multilateral labor costs and the dollar wages paid in China. This third term is actually an interaction between the Chinese import share, $(s_y N_y)$, and the multilateral labor costs relative to the Chinese wage. An increase in the Chinese share lowers U.S. import prices provided that $\ln \tilde{E}_m > \ln(\bar{e}_y w_y)$. The coefficient of this interaction term is B, which depends on the Chinese and Mexican import shares for each variety in (21c). While B is not a constant in theory, we shall treat it as constant over time (and across industries) in our estimation.

In practice the real exchange rate is constructed as an index, and it is quite difficult to meaningfully compare its level with the level of Chinese dollar wages. So when estimating (21) we shall re-write it as:[5]

$$\ln P_m = \frac{1}{(N-1)} + [1 - B(s_y N_y)] \ln \tilde{E}_m + B(s_y N_y) \ln(\bar{e}_y w_y) + \left(\frac{\alpha_x - \alpha_y}{\gamma} \right) B(s_y N_y)(1 - s_y N_y). \tag{22}$$

The multilateral labor costs $\ln \tilde{E}_m$ now appears with a coefficient less than unity, in the second term on the right. The magnitude of that coefficient depends on the Chinese import share, which enters as an interaction with $\ln \tilde{E}_m$. An increase in the Chinese share reduces the extent of exchange rate pass-through. The third term on the right of (22) is an interaction between the Chinese import share and Chinese dollar wages. If wages where treated as constant over the estimation period, then the third term is just the Chinese share itself, which can enter with a positive or negative coefficient (depending on the sign of $\ln(\bar{e}_y w_y)$); alternatively, the Chinese wages can be treated as a time trend. The final term on the right of (22) is another interaction term arising from the translog specification, between the Chinese share and one minus that share, which enters with a positive coefficient since $(\alpha_x - \alpha_y)/\gamma > 0$.

5. Pass-through in the United States

With these initial theoretical results, we turn to an empirical test of the model using data for disaggregate U.S. imports. In particular, we test the hypothesis that having more competition

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[5] Since our model is structural, in principle we could back out the structural parameters from the reduced form regressions. But since we only estimate one of these equations, the import price equation without the import demand equation, it is not possible to identify the structural parameters.

from China results in lower pass-through coefficients during the 1990s. We first discuss the data used, and then estimate the pricing equation.

International Data

We make use of a dataset constructed by Feenstra, Reinsdorf and Slaughter (2007). The dataset uses detailed monthly price data gathered by the International Price Program (IPP) at the Bureau of Labor Statistics (BLS) to construct Törnqvist price indexes from September 1993 to December 1999. The use of these indexes are preferred to the Laspeyres versions that are published by BLS, and follow our definitions in (18) more closely.[6] Feenstra, Reinsdorf and Slaughter (2007) use these data to analyze the Information Technology Agreement (ITA), which eliminated tariffs on all high-technology products beginning in 1997. Because their focus is on the ITA products, which requires special treatment for tariffs, and few of these products were supplied by China over the 1993-99 period, we focus here on non-ITA products.

Törnqvist price indices for import prices are constructed for each 5-digit Enduse industry using annual trade weights. From month t-1 to t in import sector j, the Törnqvist price index is:

$$P_{Mj}^{t-1,t} = \exp\left[\sum_{i \in I_j} w_{mi}^t \ln\left(\frac{p_{mi}^t}{p_{mi}^{t-1}}\right)\right], \tag{23}$$

where: p_{mi}^t denotes the price for disaggregate import commodity i in month t;[7] I_j is the set of commodities included in a particular import or export 5-digit Enduse industry j; and the weights w_{mi}^t denote the *annual* import shares for commodity i within industry j.[8]

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[6] The Törnqvist price indexes were constructed for the study by Alterman, Diewert and C. Feenstra (1999), which compared alternatives to the Laspeyres formula now used by IPP.

[7] The disaggregate import and export prices that we start with are at the "classification group" level use by BLS, which is similar to the HS 10-digit level.

[8] Though a proper monthly price index would use monthly trade weights, at this level of disaggregation these monthly weights are too volatile to be reliable, so the annual weights are used instead.

In addition to the import price index, we have constructed several other indexes: (i) the price index of *exports* for each 5-digit Enduse industry, denoted $P_{Xj}^{t-1,t}$, which uses the disaggregate export prices p_{xi}^{t} in a Törnqvist formula like (23); (i) a price index of *ad valorem* tariffs for each 5-digit Enduse industry, denoted by $Tar_{j}^{t-1,t}$, which uses disaggregate tariffs in a Törnqvist formula like (23); (iii) and a weighted average of the exchange rate times the producer price indexes (PPI) for U.S. trading partners, denoted by $Exch\_PPI_{j}^{t-1,t}$. In this index we start with nominal exchange rates times the PPI for each country, average these across source countries for U.S. imports (using import country weights), and then aggregate these across commodities again using the Törnqvist formula (with import commodity weights).

We gauge Chinese competition by the share of U.S. import purchases coming from China plus Hong Kong, or what we simply call the Chinese import share, within each 5-digit Enduse industry. These are measured from annual U.S. trade data from Feenstra, Romalis and Schott (1989). The Chinese import shares in each broad Enduse sector are illustrated in Figure 1. For the entire sample used in the regression analysis below, including capital goods, automobiles and parts, consumer goods and chemicals, but excluding all products covered by the ITA, the average share of Chinese imports grew steadily from 9% in 1993 to 14% in 1999.[9] The highest Chinese import share occurs in consumer goods, where the share rises from 16 to 24% over the course of the sample. In contrast, the Chinese share of capital goods accounted for only 1 to 2.5% of U.S. imports, and the Chinese share in ITA products fell from 7.5% to 5% over the period.

For comparison, in Figure 2 we illustrate the North American share of U.S. imports, defined as the import share coming from Canada plus Mexico. For the total sample of non-ITA

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[9] The rise in China's share came at the expense in part of other Asian exporters, some of which fixed their own exchange rates during this period.

products, the North American share was relatively flat, growing from 20% in 1993 to 23.5% in 1999. For the ITA products, the North American share increased the most, from below 20% to 27%. The North America share of consumer goods grow modestly from an initial low of 12% to 16.5% in 1999, while capital goods (which exclude autos) had a higher share but were generally flat and even declined over certain parts of the sample period.

Impact of Chinese Competition on Exchange Rate Pass-through

Cumulating the monthly indexes defined above, let P^t_{Mj}, P^t_{Xj}, Tar^t_j, and $Exch*PPI^t_j$ denote the cumulative indexes of import prices (tariff-inclusive), export prices, tariffs, and the exchange rate times the PPI for trading partners, in each 5-digit Enduse industry. We shall estimate the pass-through of exchange rates by pooling across a large subset of U.S. import data. All of the regressions described in Table 1 draw on Enduse categories 2 (capital goods), 3 (automobiles and parts) and 4 (consumer goods excluding automobiles). We exclude agricultural goods and most raw materials (Enduse 0 and 1).[10] But chemicals, Enduse 125, comprises several large and important categories of goods and hence is included as well.

We initially consider the following price regression in Table 1:

$$\ln P^t_{Mj} = \alpha_j + \sum_{\ell=0}^{9} \beta_\ell \text{Exch\_PPI}^{t-\ell}_j + \gamma \ln P^t_{Xj} + \varepsilon_{jt}, \tag{24}$$

where α_j is a 5-digit Enduse fixed effect, and we include the current monthly value and 6 lags of the effective exchange rate $\text{Exch\_PPI}^{t-\ell}_j$. Generally, pass-through regressions should include prices of goods that compete with the imports, such as domestic U.S. prices. Because these price

[10] The agriculture and raw materials Enduse categories (0 and 1, respectively) do not always match imports and exports, and hence our U.S. export prices cannot be used as a control in the import price equation. Also excluded are all 5-digit Enduse industries that contain some products covered by the ITA. After these selections, the dataset includes 41 5-digit Enduse categories, or roughly 40 percent of total trade value over the sample period.

indexes are not available on an Enduse basis for the U.S., we have instead included the U.S. export prices P_{Xj}^{t} in each 5-digit Enduse industry.

Panel (A) of Table 1 shows the results using the entire sample of non-agricultural, non-ITA products. The fixed-effects ordinary least squares (FE-OLS) estimate of regression (1) shows incomplete pass-through of exchange rates of 0.40, with a smaller coefficient on the export price. The remaining specifications test the effect of Chinese competition on pass-through, by interacting the exchange rate with the share of Chinese imports in each Enduse category:

$$\begin{aligned}\ln P_{Mj}^{t} = \alpha_j + \sum_{\ell=0}^{6}\beta_\ell \text{Exch\_PPI}_j^{t-\ell} + \sum_{\ell=0}^{6}\delta_\ell[\text{Exch\_PPI}_j^{t-\ell} \times \text{Share}_{jchina}^{t}] \\ +\gamma \ln P_{Xj}^{t} + \theta' Z_j^t + \varepsilon_{jt}.\end{aligned} \tag{25}$$

The sum of the coefficients δ_ℓ on the interaction term is the incremental pass-through due to changing the China share from zero to one. The additional terms Z_j^t appearing in (25) are control variables such as imports tariffs, the Chinese share of imports and other terms suggested by (22).

In regression (2) of Table 1(A), we include the interaction between the exchange rate and the Chinese import share. The FE-OLS estimate of $\sum_\ell \delta_\ell$ is positive but small. From the structural equation in (22), however, we know that additional controls are needed: treating the Chinese wage $\ln(\bar{e}_y w_y)$ as a constant, we should include the Chinese import share itself as a control, as shown in regression (3). In that case, the interaction term of the exchange rate with the Chinese share becomes negative, with a coefficient of –0.4, and statistically significant.

In regression (4) we further add other controls suggested by the structural equation (22): by treating the Chinese wage $\ln(\bar{e}_y w_y)$ as a time trend, we should also include the interaction between the Chinese share and time; and the final term in (22) is an interaction between the Chinese share and one minus that share. We also include import tariffs; even though the import prices are tariff-free, changes in the tariff levels will still affect import prices under imperfect competition, as in our model. Including these additional controls more than doubles the magnitude of OLS coefficient on the interaction term, from –0.4 to –0.95. To interpret the estimate of –0.95, an increase in the Chinese share from 9% to 14%, as occurred during the sample period, lowers pass-through by 0.95×0.05 = 0.047, or roughly 10% of its estimated magnitude over our sample period 1993–1999.

The FE-OLS estimates discussed so far are consistent, but the standard errors are incorrect if the data are nonstationary. In fact, we are unable to reject nonstationarity in the logged series of import prices, export prices and effective exchange rate variables at the 5% level, using the Im, Pesaran and Shin (IPS) panel unit root test, assuming individual effects and trends. We further perform tests to determine whether these three variables are cointegrated. Specifically, IPS panel unit root tests like those above are conducted on the residuals from regression (4). We reject the unit root in the residuals at the 1% level, supporting a hypothesis of cointegration. This result likely reflects the fact that we are using disaggregated industry-level data rather than full national aggregate import prices, where the latter is the norm in the macro literature. Aggregation bias, of the type demonstrated in Imbs *et al* (2005), is less likely to contaminate our industry- level data.

Consequently, we estimate our pass-through regressions taking account of cointegration, rather than estimating in first differences. Fortunately, a new estimator ‘pooled mean group’ (PMG) estimator is available in STATA, due to Pesaran, Shin and Smith (1997, 1999) and coded by Blackburne and Frank (2007), which is maximum likelihood for cointegrated panels.[11] To explain this estimator, denote the right-hand side variables in (25) that have unit-roots by X_j^t, which includes the effective exchange rate $Exch\_PPI_j^t$, its interaction with the Chinese share, and the exports price $\ln P_{Xj}^t$. Denote the coefficients of these lagged variables by the vector $\eta_{j\ell} = (\beta_{j\ell}, \delta_{j\ell}, \gamma_{j\ell})'$, $\ell = 0,...,q,$ where we assume the same lag length q for all variables but allow the coefficients to vary across Enduse categories j. Further add the auto-regressive term $\rho_j \ln P_{Mj}^{t-1}$ onto the right of (25).[12] Then the resulting equation can be equivalently written in the error-correction form as:

$$\Delta \ln P_{Mj}^t = \alpha_j + \sum_{\ell=0}^{q-1} \eta'_{j\ell} \Delta X_j^{t-\ell} + \theta'_j \Delta Z_j^t + \phi_j \left(\ln P_{Mj}^{t-1} - \eta' X_j^{t-1} \right) + \varepsilon_{jt}, \tag{26}$$

where $\phi_j = -(1-\rho_j) < 0$ indicates the speed of adjustment to the long run, and we assume that $\eta = -\sum_{\ell=0}^{q} \eta_{j\ell} / \phi_j$. That is, the PMG estimator allows for differing short-run coefficients $\eta_{j\ell}$ and $\theta_{j\ell}$ across Enduse categories, but assumes that the long-run coefficients η appearing within the error-correction vector are identical. This assumption allows us to pool across Enduse categories to obtain the maximum likelihood long-run estimates.

In the remaining columns of Table 1 we show the PMG estimates. In specification (5) using only the effective exchange rate and the export price, we obtain exactly the same pass-through estimates of 0.4 as in the OLS estimates. Adding the interaction with the China import share in specification (6), the coefficient is tightly estimated at –0.6, and remains about the same

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[11] This estimator is also discussed by Breitung and Pesaran (2005, p. 37), and is invoked by the `xtpmg` command.

[12] Actually, the `xtpmg` estimator allows for autoregressive lags of the dependent variable up to length p, where both p and q are chosen by the program.

when the import tariffs are added into the long-run relationship in specification (7). Note that the PMG estimator does not rely on using the China share as a control, or the China share times one minus the share, because these variables are omitted from estimation. This occurs because the China share is measured on an annual basis, so in first-differences it varies only in January of each year. STATA omits this variable from estimation within the first-differenced variables $\Delta X_j^{t-\ell}$ in (26), and hence, does not accept it into the error-correction term either.

A final coefficient reported in Table 1 is the estimate of the adjustment parameters ϕ_j, which are averaged across the Enduse categories. The averaged estimate is –0.17 or –0.18, and is significantly difference from zero. If the panel was not cointegrated, then we would expect this coefficient to be zero, so its estimate further supports the cointegration of the panel.

A greater impact of the rising Chinese share is obtained from the subset of the data for consumer goods, in Table l panel (B), in which Chinese competition is strong and rising. The FE-OLS specification in regression (4) has a coefficient on the interaction between the Chinese share and exchange rate of –1.16, along with a pass-through coefficient of –0.54. For this sector, the Chinese share shown in Figure 1 has increase from about 16% to 24% over 1993-1999, which lowers pass-through by $1.16\times0.08 = 0.09$, or 17% of its estimated magnitude. In the PMG estimates in specification (7), the interaction term becomes –0.73, along with a pass-through coefficient of –0.47. In this case, the rising Chinese import share lowers pass-through by $0.73\times0.08 = 0.06$, or 12% of its estimated magnitude. So according to either estimate, the impact of Chinese competition on reducing pass-through is greater for consumer goods than for the total sample of consumer goods, capital goods, autos and chemicals.

We have also examined the other major Enduse sectors within the total sample of non-

ITA commodities (i.e. capital goods, autos and chemicals), as well as the Enduse categories that include imports covered by the ITA. The results are sensitive to the estimator (FE-OLS versus PMG), as well as to the controls that are included in the specification. Sometimes the interaction of the China import share with the exchange rate has a negative coefficient, as implied by our theory, but in other specifications with the same Enduse category, the interaction term can become positive. The common feature of all these Enduse categories is that they have a small share of imports from China during the sample period. In contrast, consumer goods shown in Table 1(B) have a large and rising import share from China. So we conclude, not surprisingly, that the impact of Chinese competition on pass-through can be reliably estimated only for goods where the imports from China are substantial.

6. Free Entry of Firms

In the previous section we solved for the multilateral pass-through in (19) while treating the number of products sold by Mexico and China as fixed. But as suggested by Proposition 2, an increase in the number of products sold into the U.S. can dampen pass-through. We now explore the impact of free entry by firms. We begin by computing the full short-run equilibrium of the model, with fixed wages but allowing for free entry; we also determine the change in the Chinese money supply needed to sustain the fixed exchange rate. Allowing for free entry and the endogenous Chinese money supply results in a five equation system to determine equilibrium, which we will analyze by simulation.

With expenditure in the United States equal to M_z (from the cash-in-advance constraint), and the fraction $(1-\beta)$ spent on the differentiated good, the expenditure on each Mexican and Chinese good sold in the U.S. is $s_x(1-\beta)M_z$ and $s_y(1-\beta)M_z$, respectively. From the first-order condition (13), we readily calculate that profits (before deducting fixed costs) are then

$\pi_i = s_i(1-\beta)M_z/\eta_i$. The free-entry or zero-profit condition in Mexico and China ensures that profits equal fixed costs $s_i(1-\beta)M_z/\eta_i = e_i w_i f_i$. Using the formula for the elasticity of demand, the free-entry condition can be written as:

$$s_i^2\left[\frac{(1-\beta)M_z}{e_i w_i f_i}\right] - s_i - \gamma\left(\frac{N-1}{N}\right) = 0, \quad i = x, y. \tag{27}$$

This condition along with (20) provides 4 equations in 4 unknowns: s_i and N_i, i = x,y.

A solution to this system is not guaranteed, however. For example, if A = 0 then it is readily apparent that N_x and N_y do not appear at all in the system: we have $s_i = 1/N$ from (20), and then we solve for N from (27) provided that $e_x w_x f_x = \bar{e}_y w_y f_y$. In that case we solve for the total number of products sold in the U.S. but with an indeterminate number coming from each country. Conversely, if $e_x w_x f_x \neq \bar{e}_y w_y f_y$ then we would obtain a boundary solution where either all products come from Mexico or all come from China. These situations also apply to a model with CES demand and two exporting countries, where it is most likely that zero-profits are obtained in only one exporting country (with negative profits in the other); or, if zero-profits hold in both exporting countries because costs are identical, then we could not solve for the number of products exported from each but only the total number of products exported.

When A > 0, however, then it is becomes possible to find a solution for N_x and N_y both positive and zero profits in both countries, as shown by the following result:

<u>Proposition 3</u>

Let $B_i \equiv (1-\beta)(M_z/e_i w_i f_i)$ denote the U.S. expenditure on the differentiated good as compared to the fixed costs of producing a new variety in each country, i = x,y. When A > 0 and $\gamma = 1$, a solution to (20) and (27) exists with $N_i > 0$, i = x,y, and N > 2 provided that:

(a) $B_y > B_x > 4$;

(b) $A \in (A_y, A_x)$, where the interval $(A_y, A_x) \subset R^+$ is non-empty.

When $A > 0$ then to obtain a zero-profit solution we also need to have $B_y > B_x$ as shown by (a), which means that the Mexican fixed costs must be higher than the Chinese fixed costs, $e_x w_x f_x > \bar{e}_y w_y f_y$. The further condition that $B_y > B_x > 4$ ensures that the equilibrium number of product N exceeds 2, so that at least one product can be produced in each country.[13] Condition (b) states the U.S. taste bias towards Mexican varieties must exceed a lower bound $A_y > 0$, but also less than an upper-bound A_x. The interval (A_y, A_x) is defined by the values of B_x and B_y, as shown in the Appendix. Provided that these conditions are met then there exists a zero-profit equilibrium with varieties exported to the U.S. by both Mexico and China.

Having established the existence of a zero-profit equilibrium, we should also close the model to show how the Chinese money supply M_y and the peso exchange rate e_x are established. Recall from section 2 that with the cash-in-advance constraints, the goods market equilibrium condition for the U.S. can also be interpreted as the asset market equilibrium condition for dollars. That gave use one equilibrium condition to determine M_y and e_x. The other equilibrium condition comes from examining the goods market equilibrium in either China or Mexico, which will be equivalent to the asset market equilibrium for that currency.[14]

Focusing on China, one unit of the differentiated good is produced with one unit of labor. Then the labor used to produce exports to the U.S. is:

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[13] It turns out that the equilibrium number of products satisfies $\sqrt{B_x} < N < \sqrt{B_y}$, which generalizes the "square root rule" for the equilibrium number of products found by Bergin, Feenstra and Hanson (2007).

[14] By Walras' law, goods/asset market equilibrium in any two countries will imply that that the equilibrium condition holds in the third country.

$$\text{Labor demand from Chinese exports to U.S.} = \frac{N_y s_y (1-\beta) M_z}{\bar{e}_y p_y} + N_y f_y \,,$$

where the first term is the labor used in production, and the second is labor used in fixed costs. We assume that the differentiated good is *only* demanded by the United States, and that China does not export anything to Mexico. The Chinese consumers devote β of their expenditure to a locally-produced homogeneous good. Then the labor used to produce local goods in China is:

$$\text{Labor demand from Chinese local consumption} = \frac{\beta M_y}{w_y}.$$

It follows that the labor market equilibrium condition in China is:

$$\frac{s_y N_y (1-\beta) M_z}{\bar{e}_y p_y} + N_y f_y + \frac{\beta M_y}{w_y} = L_y \,. \tag{28}$$

We can simplify this condition by using the zero-profit condition in China, which is $s_y (1-\beta) M_z / \eta_y = \bar{e}_y w_y f_y$, and also noting that $p_y = w_y \eta_y / (\eta_y - 1)$. Using both these conditions, as well as the short-run cash-in-advance constraint for China, $\overline{w}_y L_y = M_y$, then we can multiply both sides of (28) by the Chinese wage and simplify to obtain:

$$\frac{s_y N_y (1-\beta) M_z}{\bar{e}_y} + \beta M_y = M_y \,. \tag{28'}$$

The first term on the right of (28') is the yuan used to purchase the Chinese exports to the U.S., and the second term is the yuan used by Chinese consumers to purchase their local good, so these must equal the available currency, M_y. It follows from (28') that the equilibrium Chinese money supply is: $M_y = s_y N_y M_z / \bar{e}_y$. Substituting this back into (3), we obtain:

$$e_x M_x = s_x N_x M_z \,. \tag{29}$$

Holding fixed the Mexican money supply M_x, then (29) gives us the equilibrium peso exchange rate e_x that is implied by the U.S. money supply; in the background, we are also solving for the Chinese money supply from (28'). Notice that $(s_x N_x)$ is interpreted as the share of the differentiated-goods market in the U.S. that is devoted to Mexican varieties, and we could expect this share to fall with peso appreciation. If that is the case, then an expansion in the U.S. money supply will lead to a *smaller* equilibrium appreciation of the peso.

The full set of short-run equilibrium conditions are (20), (27) and (29), which are five equations in five unknowns: the shares s_x and s_y, the number of products N_x and N_y, and the equilibrium peso exchange rate e_x in (29). We shall use simulations to perform the comparative statics on this system of equations. There are several properties that we find hold consistently in the simulations, and can be used to suggest the results that we should expect. Specifically, we find that an increase in the U.S. money supply leads to:

$$M_z \text{ rises} \quad \Rightarrow \quad e_x,\ N_y \text{ and } N \text{ all rise, with } \Delta \ln N_y > \Delta \ln N. \tag{30}$$

It is intuitive that the increase in the U.S. money supply leads to an appreciation of the peso and a rise in the number of varieties exported from China and in total; we find the greatest relative increase in the number of Chinese varieties.

With this result, the change in the multilateral index P_m due to entry can also be examined. As before, we consider the change in (17a) holding its weights constant, which is (18a). Using (15a), the change in the import prices arising only from the increase in export variety (i.e. from the change in N_x, N_y and N) is:

$$d\ln(e_x p_x) = \frac{-dN}{\gamma(N-1)^2} + \left[\frac{dN_y}{(2N-1)} - \frac{2N_y dN}{(2N-1)^2}\right]\frac{A}{\gamma}, \tag{31a}$$

and $$d\ln(\bar{e}_y p_y) = \frac{-dN}{\gamma(N-1)^2} - \left[\frac{dN_x}{(2N-1)} - \frac{2N_x dN}{(2N-1)^2}\right]\frac{A}{\gamma}. \tag{31b}$$

Combining (31) and (18a), we see that the multilateral index changes by:

$$d\ln P_m = (s_x N_x) d\ln(e_x p_x) + (s_y N_y) d\ln(\bar{e}_y p_y)$$

$$= \frac{-dN}{\gamma(N-1)^2} + \left[\frac{(dN_y N_x s_x - dN_x N_y s_y)}{(2N-1)} - \frac{2(s_x - s_y) N_x N_y dN}{(2N-1)^2}\right]\frac{A}{\gamma}. \tag{32}$$

The first terms and the third terms on the right of (32) are negative, since $s_x > s_y$, $A > 0$, and total variety N is growing due to the U.S. monetary expansion. This expansion in variety reduces markups and prices because of a competitive effect of having more varieties sold. The second term on the right of (26) depends on the relative growth of Chinese versus Mexican export varieties, and will tend to be positive when Chinese varieties grow more. So the overall impact of free entry on the multilateral price index is ambiguous in general, but will be negative whenever the first the third terms on the right of (32) dominate the second term.

Given that closed form solution is not possible when the number of varieties is endogenous, we use numerical solution to study the equilibrium. We choose values for the parameters and exogenous variables as follows. Fixed costs of entry for export firms from Mexico are set to ensure that the number of firms and hence competition are sufficient to imply a markup of 20% over cost (f_x =0.5). The entry cost in China is set so that the number of entrants implies that Chinese firms represent about a 24% share of the U.S. imported goods market (f_y=0.005), reflecting the Chinese share in the U.S. consumer goods market at the end of our data sample. We conjecture a strong bias in U.S. preferences toward Mexican goods (α_x = 0.9/20 and α_y = 0.1/20, where 20 is the maximum number of differentiated products) and will consider robustness checks to alternative calibrations. We assume no other home bias in preferences (β = 0.5), and we start with the standard translog case of γ = 1. For simplicity, exogenous money supplies are set to imply steady state wages of unity for both countries, and a unitary steady sate exchange rate for China.

Table 2 reports pass-through levels for the benchmark as well as several alternative calibrations. The experiment is defined as a 10% rise in U.S. money, which in this calibration of the model generates a 1% depreciation of the dollar in the trade-weighted effective exchange rate defined above. The benchmark calibration indicates that it is possible to achieve a level of pass-through at or below the level of 0.3 found in our empirical estimates, and near the level of 0.2 observed in some recent empirical studies. Much of this drop in pass-through comes from free entry of new firms and the competitive effect noted above. Without free entry, while pass-through in this model is still well below unity, it is still well above the empirical estimates. The table confirms the conjecture above that a dollar depreciation would induce a rise in the total number of firms through new entry from China; there is exit among the Mexican firms, since their costs are rising relative to their Chinese competitors. Entry contributes to the low pass-through in multiple ways. First, the rise in competition forces all firms to lower their markups, corresponding to the first term in equation (32) above. This is a direct implication of the translog preferences, and is not dependent on China. However, since the entry here is composed of Chinese firms, the rise in the China share reduces the willingness of the remaining Mexican firms to raise their prices with rising costs, which is an additional effect lowering pass-through. Given that our results arise from a very strong and instantaneous entry response, results would likely be dampened if we incorporated entry lags or sunk costs into the model.

Sensitivity analysis indicates that for this calibration of the model the level of home bias (β) and the bias in U.S. import preferences toward Mexico (α_x), have only moderate effects on the degree of pass-through. But the translog parameter γ has larger effects, especially working through the competitiveness channel. In fact, for a value of $\gamma = 5$, the model shows that pass-through can easily become negative.

Next, we explore the role of the Chinese share by simulating a case where Chinese firms are fixed at a share of zero. In this case there is full pass-through of the dollar depreciation to import prices. Without the need to compete against firms shielded by a fixed exchange rate, Mexican firms are free to raise their prices to reflect their rising costs. Further, the pure competitive effect described above also disappears, because rising Mexican costs completely offset the rise in sales in the U.S. due to the monetary expansion, so there is no new entry to raise competition.

Finally, we use the simulation model to study the implications of China allowing greater exchange rate flexibility. Suppose a monetary policy rule that balances exchange rate stability against monetary stability, with a weight 1-ψ on exchange rate movements:

$$\Psi\left(\log M_y - \log \overline{M_y}\right) = \left(1-\Psi\right)\left(\log e_y - \log \overline{e_y}\right), \qquad 0 \le \Psi \le 1 . \tag{33}$$

Table 3 shows how progressively higher values of ψ imply a greater yuan appreciation in our experiment, where column 2 shows Chinese currency appreciation as a ratio to currency appreciation for Mexico. As Chinese exchange rate flexibility approaches that of Mexico, the pass through gradually rises until it becomes complete. Given that China appears in reality to be on a path of greater exchange rate flexibility relative to the dollar, this simulation would seem to indicate we should expect pressure for pass through coefficients to rise, possibly reversing the recent trend of falling pass-through observed in data.

7. Conclusion

This paper studies how the upward trend in China's share of U.S. imports could lower pass-through of exchange rates to U.S. import prices. It develops a theoretical model showing that the presence of exports from a country with a fixed exchange rate could alter the competitive environment in the U.S. market; in particular, it induces exporters from other countries to reduce their markups in the face of U.S. depreciations. This effect is amplified when the model allows free entry of new exporters, as a U.S. depreciation tends to encourage exit of exporters with flexible exchange rates, and hence further raises endogenously the share of suppliers with fixed exchange rates like those from China. The model predicts that certain conditions are needed to make such a 'China explanation' for falling pass-through work. Prominent among these conditions is that Chinese exports in a given industry involve a larger number of varieties with a smaller average market share per variety than is true for exporters from other competing countries. The model indicates that this condition's validity depends on country biases in U.S. preferences. The model also produces a log-linear structural equation for pass-through regressions involving the china share of imports. Panel regressions support the role of a rising China share in lowering pass-through in the U.S.

Viewed more broadly, the results developed in this paper need not be restricted to the case of China, but are relevant for all trading partners with a fixed exchange rate. Hence, the model predicts that pass-through could fall further if the market share of trading partners with fixed exchange rates were to rise; likewise, pass-through could begin to rise if the share of exchange rate fixers were to fall over time.

In conclusion, we address a criticism in Marazzi *et al* (2005) that a China-based explanation works better for the case of dollar depreciation, such as that in the mid 2000s, than it does a dollar appreciation, as that experienced in the late 1990s. To the contrary, our model implies that pass-through is low, regardless of the direction of the exchange rate movement. Since pass-through is a matter of changes in price level relative to some previous period rather than an absolute level, it is not important to our theoretical argument that the absolute levels of Chinese prices tend to be lower on average than prices of other exporters. What matters is that the change in costs and hence prices of Chinese firms tend to be less in response to exchange rate movements, and this makes exporters from competing countries reluctant to change their prices. This effect applies equally well if exchange rates and hence costs are rising or falling.

Appendix

Proof of Proposition 1:

Write (4) in matrix form as:

$$\ln e(p) = \alpha_0 + \alpha' \ln p + \tfrac{1}{2} \ln p' \Gamma \ln p, \tag{A1}$$

where α is the column vector $(\alpha_1,\ldots,\alpha_{\tilde{N}})'$; $\ln p$ is the column vector $(\ln p_1,\ldots,\ln p_{\tilde{N}})'$; and Γ is the symmetric matrix with elements γ_{ij}. The share equations are obtained by differentiating (A1), obtaining:

$$s = \alpha + \Gamma \ln p_t, \tag{A2}$$

Using the share equation (A2), we can rewrite the expenditure function as,

$$\ln e(p) = \alpha_0 + \tfrac{1}{2}(\alpha + s)' \ln p\,. \tag{A3}$$

We partition the share vector as $s^1 = (s_1,\ldots,s_N)' > 0$, and $s_t^2 = (s_{N+1},\ldots,s_{\tilde{N}})' = 0$. We partition the price vectors p^1 and p^2 in the same way, and the vector α and the matrix Γ:

$$\alpha = \begin{bmatrix} \alpha^1 \\ \alpha^2 \end{bmatrix}, \text{ and } \quad \Gamma = \begin{bmatrix} \Gamma^{11} & \Gamma^{12} \\ \Gamma^{21} & \Gamma^{22} \end{bmatrix}. \tag{A4}$$

The diagonal elements of Γ are $\Gamma^{11} = -(\gamma / \tilde{N})[\tilde{N}\ I_N - L_{NxN}]$, where L_{MxN} denotes an MxN matrix with all elements unity, $\Gamma^{22} = -(\gamma / \tilde{N})[\tilde{N}\ I_{(\tilde{N}-N)} - L_{(\tilde{N}-N)x(\tilde{N}-N)}]$, and the off-diagonal elements are $\Gamma^{12} = (\gamma / \tilde{N}) L_{Nx(\tilde{N}-N)}$, and $\Gamma^{21} = (\gamma / \tilde{N}) L_{(\tilde{N}-N)xN}$.

Then the share equations can be rewritten using the reservation prices $\tilde{p}^2$ as:

$$s^1 = \alpha^1 + \Gamma^{11} \ln p^1 + \Gamma^{12} \ln \tilde{p}^2 + \beta^1 \ln(Y/P), \tag{A5}$$

$$0 = \alpha^2 + \Gamma^{21} \ln p^1 + \Gamma^{22} \ln \tilde{p}^2 + \beta^2 \ln(Y/P). \tag{A6}$$

Using (A6), we can solve for the reservation prices as:

$$\ln \tilde{p}^2 = -(\Gamma^{22})^{-1}(\alpha^2 + \Gamma^{21} \ln p^1). \tag{A7}$$

Substituting these reservations prices into the expenditure function (A3) using $s^2 = 0$, to obtain:

$$\begin{aligned}
\ln e(p) &= \alpha_0 + \tfrac{1}{2}(\alpha^1 + s^1)' \ln p^1 + \tfrac{1}{2}\alpha^{2\prime} \ln \tilde{p}^2 \\
&= \alpha_0 + \tfrac{1}{2}(\alpha^1 + s^1)' \ln p^1 + \tfrac{1}{2}\alpha^{2\prime}(\Gamma^{22})^{-1}(\alpha^2 + \Gamma^{21} \ln p^1) \\
&= a_0 + \tfrac{1}{2}(a^1 + s^1)' \ln p^1,
\end{aligned} \tag{A8}$$

where the last line is obtained by defining:

$$a^1 \equiv \alpha^1 - \Gamma^{12}(\Gamma^{22})^{-1}\alpha^2, \tag{A9}$$

$$a_0 \equiv \alpha_0 - (1/2)\alpha^{2\prime}(\Gamma^{22})^{-1}\alpha^2. \tag{A10}$$

where we have used the symmetry of Γ so that $\Gamma^{21\prime} = \Gamma^{12}$.

Likewise solving for s^1 from (A6), we obtain:

$$\begin{aligned}
s^1 &= \alpha^1 + \Gamma^{11} \ln p^1 - \Gamma^{12}(\Gamma^{22})^{-1}(\alpha^2 + \Gamma^{21} \ln p^1) \\
&= a^1 + C^{11} \ln p^1,
\end{aligned}$$

where the final line is obtained by defining:

$$C^{11} \equiv \Gamma^{11} - \Gamma^{12}(\Gamma^{22})^{-1}\Gamma^{21}. \tag{A11}$$

Substituting (A12) back into the expenditure function (A8):

$$\ln e(p) = a_0 + \tfrac{1}{2} \ln p^{1\prime} C^{11} \ln p^1. \tag{A12}$$

To complete the proof, we need to show that the parameters in (A9)-(A11) satisfy (8)-(10), once we make use of the original symmetry restrictions in (6).

Consider the definition of C^{11} in (A11). Notice that from (6) we can express Γ^{11} as Γ^{11} = $(\gamma/\tilde{N})[-\tilde{N}\ I_N + L_{NxN}]$, and $\Gamma^{12} = (\gamma/\tilde{N})[L_{Nx(\tilde{N}-N)}]$. Substituting these into (A11):

$$C^{11} = \left(\frac{\gamma}{\tilde{N}}\right)[-\tilde{N}\ I_N + L_{NxN}] + \left(\frac{\gamma}{\tilde{N}}\right)L_{Nx(\tilde{N}-N)}\,[\tilde{N}\ I_{(\tilde{N}-N)} - L_{(\tilde{N}-N)x(\tilde{N}-N)}]^{-1}\,L_{(\tilde{N}-N)xN}.$$

Notice that the matrix $[\tilde{N}\ I_{(\tilde{N}-N)} - L_{(\tilde{N}-N)x(\tilde{N}-N)}]$ has an eigenvector of $L_{(\tilde{N}-N)x1}$ (i.e. a column vector of unity), with the associated eigenvalue of N. Therefore, its inverse also has an eigenvector of $L_{(\tilde{N}-N)x1}$, with the eigenvalue of 1/N. It follows that,

$$\begin{aligned}
C^{11} &= (\gamma/\tilde{N})[-\tilde{N}\ I_N + L_{NxN}] + (\gamma/N\tilde{N})L_{Nx(\tilde{N}-N)}\,L_{(\tilde{N}-N)xN} \\
&= (\gamma/\tilde{N})[-\tilde{N}\ I_N + L_{NxN}] + [\gamma(\tilde{N}-N)/N\tilde{N})]L_{NxN} \\
&= -\gamma I_N + (\gamma/N)L_{NxN},
\end{aligned}$$

where the second line again follows by matrix multiplication and the third line by arithmetic. This establishes that (8) holds.

To establish (9), substitute Γ^{22} and Γ^{12} into (A9) to evaluate:

$$\begin{aligned}
a^1 &= [\alpha^1 - \Gamma^{12}(\Gamma^{22})^{-1}\alpha^2] \\
&= \alpha^1 + L_{Nx(\tilde{N}-N)}[\tilde{N}\ I_{(\tilde{N}-N)} - L_{(\tilde{N}-N)x(\tilde{N}-N)}]^{-1}\alpha^2 \\
&= \alpha^1 + \left(\frac{1}{N}\right)L_{Nx(\tilde{N}-N)}\alpha^2 \\
&= \alpha^1 + \left(\frac{1}{N}\right)\begin{bmatrix} \sum_{i=N+1}^{\tilde{N}}\alpha_i \\ \vdots \\ \sum_{i=N+1}^{\tilde{N}}\alpha_i \end{bmatrix}.
\end{aligned}$$

where the third line uses the eigenvalue properties definition of $[\tilde{N}\ I_{(\tilde{N}-N)} - L_{(\tilde{N}-N)x(\tilde{N}-N)}]^{-1}$.

Notice that $\sum_{i=N+1}^{\tilde{N}}\alpha_i$ equals $1-\sum_{i=1}^{N}\alpha_i$, which gives us (9).

To establish (10), substitute Γ^{22} into (A11) to evaluate:

$$
\begin{aligned}
a_0 &= \alpha_0 - (1/2)\alpha^{2\prime}(\Gamma^{22})^{-1}\alpha^2 \\
&= \alpha_0 + \left(\frac{1}{2\gamma}\right)\alpha^{2\prime}\left[I_{(\tilde{N}-N)} - \left(\frac{1}{\tilde{N}}\right)L_{(\tilde{N}-N)x(\tilde{N}-N)}\right]^{-1}\alpha^2 \\
&= \alpha_0 + \left(\frac{1}{2\gamma}\right)\alpha^{2\prime}\left[I_{(\tilde{N}-N)} + \left(\frac{1}{\tilde{N}}\right)L_{(\tilde{N}-N)x(\tilde{N}-N)} + \left(\frac{1}{\tilde{N}^2}\right)L^2_{(\tilde{N}-N)x(\tilde{N}-N)} + \ldots\right]^{-1}\alpha^2 . \\
&= \alpha_0 + \left(\frac{1}{2\gamma}\right)\left\{\sum_{i=N+1}^{\tilde{N}}\alpha_i^2 + \left(\frac{1}{\tilde{N}}\right)\left(\sum_{i=N+1}^{\tilde{N}}\alpha_i\right)^2\left[1 + \left(\frac{\tilde{N}-N}{\tilde{N}}\right) + \left(\frac{\tilde{N}-N}{\tilde{N}}\right)^2 \ldots\right]\right\} \\
&= \alpha_0 + \left(\frac{1}{2\gamma}\right)\left\{\sum_{i=N+1}^{\tilde{N}}\alpha_i^2 + \left(\frac{1}{N}\right)\left(\sum_{i=N+1}^{\tilde{N}}\alpha_i\right)^2\right\},
\end{aligned}
$$

which completes the proof. QED

Proof of Proposition 2

Using (20), we obtain: $\left(\dfrac{s_x}{s_x - s_y}\right) = \dfrac{1}{N(s_x - s_y)} + \dfrac{N_y}{N}$. It follows that:

$$\frac{d\ln P_m}{d\ln E_m} = 1 - \frac{N_y}{(2N-1)}\left(\frac{s_x - s_y}{s_x}\right) = 1 - \frac{N}{(2N-1)}\left[\frac{1}{N_y(s_x - s_y)} + 1\right]^{-1} . \tag{A13}$$

From (20), the difference in shares is $(s_x - s_y) = \left(\dfrac{N-1}{2N-1}\right)A$. This difference does not vary with N_y, for fixed N, so it follows that (A13) is decreasing in N_y, for given N.

More generally, substitute $(s_x - s_y)$ in (A13) to obtain:

$$\frac{d\ln P_m}{d\ln E_m} = 1 - \left[\frac{(2N-1)^2}{N(N-1)}\frac{1}{AN_y} + 2 - \frac{1}{N}\right]^{-1} \equiv 1 - C. \tag{A14}$$

An equi-proportional increase in N_y and N, satisfying $d\ln N_y = d\ln N = \lambda > 0$, affects C by:

$$dC = \left(\frac{\partial C}{\partial \ln N_y} + \frac{\partial C}{\partial \ln N} \right) \lambda = \frac{\partial C}{\partial \mathrm{l} N_y} N_y \lambda + \frac{\partial C}{\partial N} N \lambda \ .$$

Careful inspection of the derivatives of C shows that $dC > 0$ provided that $A < 1$. It follows that an equi-proportional increase N_y and N lowers pass-through. Since pass-through is decreasing in N_y for given N, we conclude that any change in N_y and N satisfying $d \ln N_y > d \ln N \geq 0$ will lower pass-through. QED

Proof of Proposition 3

To determine whether such a solution exists, we first solve the quadratic equations (27) to obtain the expenditure shares on the products of each country:

$$s_i = \frac{1}{2B_i}\left[1 + \sqrt{1 + 4B_i \gamma\left(\tfrac{N-1}{N}\right)}\right], \text{ where } B_i \equiv \left(\frac{\beta M_z}{e_i w_i f_i} \right), \quad i = x, y. \tag{A15}$$

Notice that s_i is decreasing in B_i. Since $A > 0$ implies that $s_x > s_y$ from (20), this will imply that $B_x < B_y$ from (A15), which is (a). Given that condition, we evaluate the difference of the shares $(s_x - s_y)$ from (A15) and the shares $(s_x - s_y)$ from (20), as:

$$f(N) \equiv \frac{1}{2B_x}\left[1 + \sqrt{1 + 4B_x \gamma\left(\tfrac{N-1}{N}\right)}\right] - \frac{1}{2B_y}\left[1 + \sqrt{1 + 4B_y \gamma\left(\tfrac{N-1}{N}\right)}\right] - \left(\frac{N-1}{2N-1} \right) A \ . \tag{A16}$$

The solution for N occurs where $f(N^*) = 0$. To establish this solution, we simplify the problem by assuming $\gamma = 1$. We compare the values of $f(\sqrt{B_x})$ and $f(\sqrt{B_y})$. Writing these out, we find that $f(\sqrt{B_x}) > 0$ and $f(\sqrt{B_y}) < 0$ provided that $A < A_x$ and $A > A_y$, defined by:

$$A_i = \left(\frac{2\sqrt{B_i} - 1}{\sqrt{B_i} - 1} \right) \left\{ \frac{1}{2B_x}\left[1 + \sqrt{1 + 4B_x \gamma\left(\frac{\sqrt{B_i} - 1}{\sqrt{B_i}} \right)}\right] - \frac{1}{2B_y}\left[1 + \sqrt{1 + 4B_y \gamma\left(\frac{\sqrt{B_i} - 1}{\sqrt{B_i}} \right)}\right] \right\} > 0,$$

for i = x,y. By careful inspection of the derivative with respect to B_i, it can be shown that this expression is decreasing in B_i, which implies that $A_y < A_x$ so the interval (A_y, A_x) is non-empty. By construction, for $A \in (A_y, A_x)$ we have $f(\sqrt{B_x}) > 0$ and $f(\sqrt{B_y}) < 0$. It follows by continuity that there exists N* with $\sqrt{B_x} < N^* < \sqrt{B_y}$ satisfying $f(N^*) = 0$.

Given N*, use (A13) to solve for the shares s_i^*, and then (20) to solve for N_i^*, i = x,y:

$$\frac{N_y^*}{N^*} = \left(s_x^* - \frac{1}{N^*}\right) \Big/ \left(\frac{N^*-1}{2N^*-1}\right) A \text{, and } \frac{N_x^*}{N} = \left(\frac{1}{N^*} - s_y^*\right) \Big/ \left(\frac{N^*-1}{2N^*-1}\right) A \text{.} \qquad \text{(A17)}$$

We need to confirm that these solution for N_i^* are both positive. Using $\gamma = 1$, the quadratic equation (20) becomes:

$$\begin{aligned} s_i^* &= \left[(s_i^*)^2 B_i - 1\right] + \frac{1}{N^*} \\ &= \left\{ \frac{1}{4B_i} \left[1 + \sqrt{1 + 4B_i \left(\tfrac{N^*-1}{N^*}\right)} \right]^2 - 1 \right\} + \frac{1}{N^*} \end{aligned}$$

To ensure $s_x^* > 1/N^* > s_y^*$ we must have:

$$\left[1 + \sqrt{1 + 4B_x\left(\tfrac{N^*-1}{N^*}\right)}\right] > 2\sqrt{B_x} \text{ and } \left[1 + \sqrt{1 + 4B_y\left(\tfrac{N^*-1}{N^*}\right)}\right] < 2\sqrt{B_y}$$

which holds if and only if,

$$\left(\frac{N^*-1}{N^*}\right) > \frac{1}{4B_x}\left[\left(2\sqrt{B_x} - 1\right)^2 - 1\right] \text{ and } \left(\frac{N^*-1}{N^*}\right) < \frac{1}{4B_y}\left[\left(2\sqrt{B_y} - 1\right)^2 - 1\right].$$

It is readily verified that $\sqrt{B_x} < N^* < \sqrt{B_y}$ ensures that both the above inequalities hold, so that $s_x^* > 1/N^* > s_y^*$. It follows from (A15) that $N_i^* > 0$, i = x,y. QED

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Figure 1: China Share of Imports

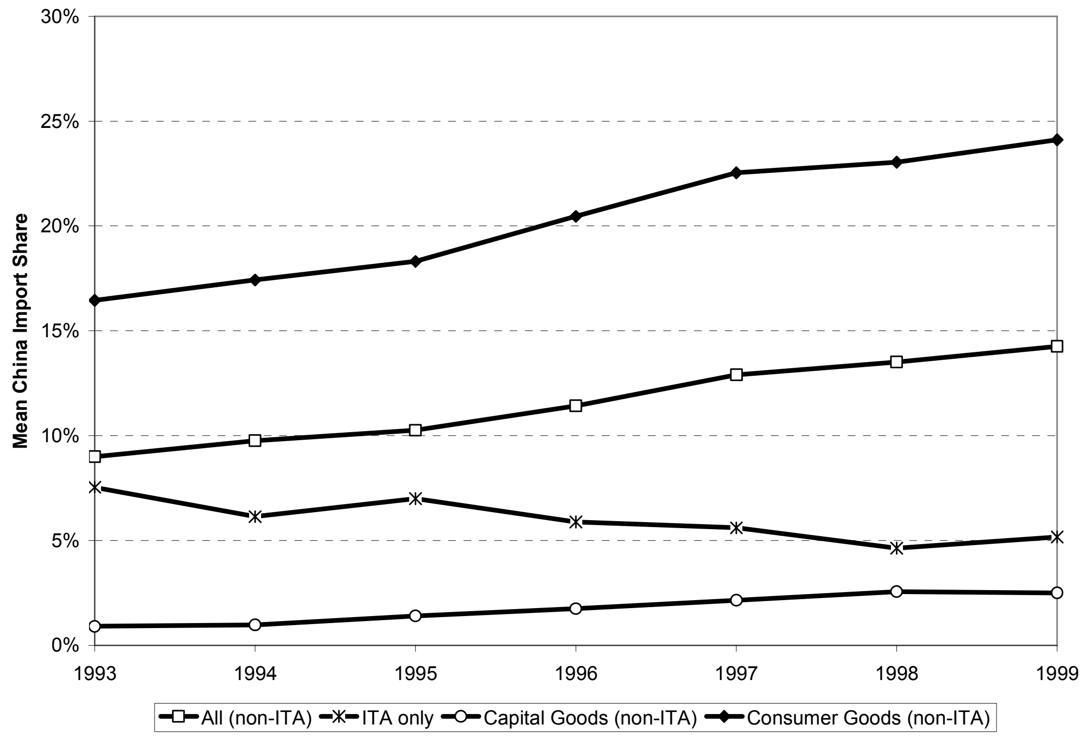

Figure 2: North America Share of Imports

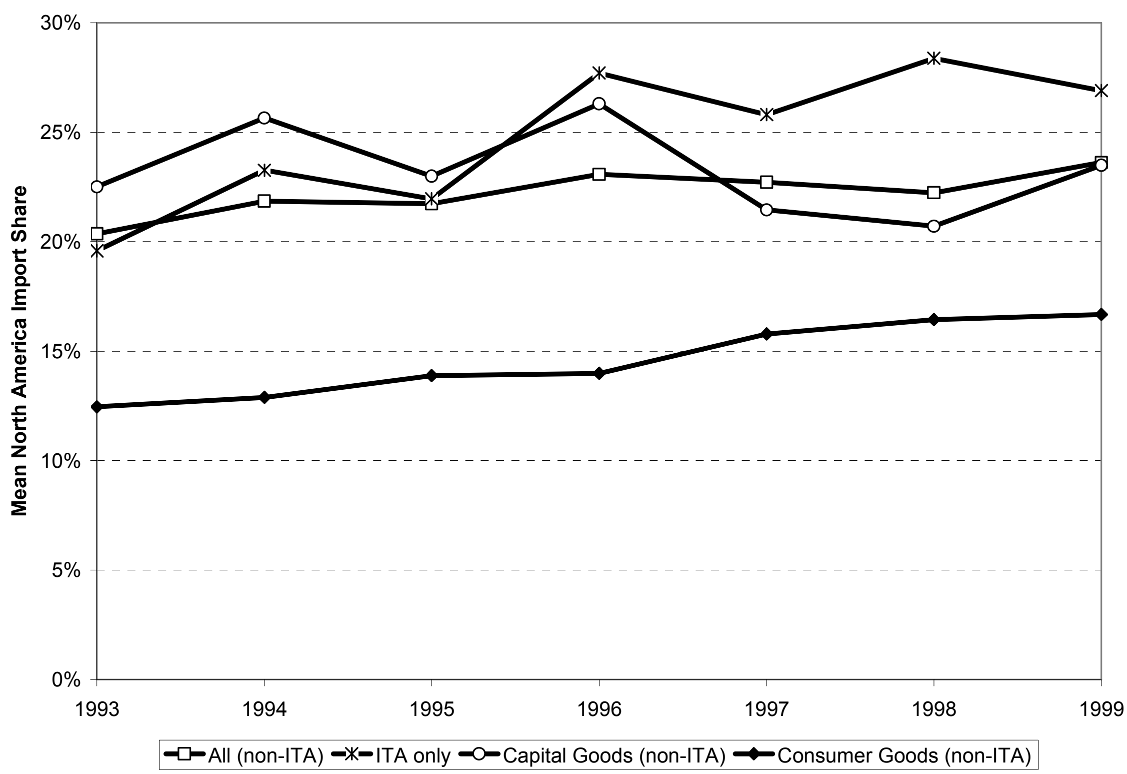

Table 1: Dependent Variable – Import Price Index

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
A. Consumer goods, capital goods, autos and chemicals (Enduse 1-4)							
	FE-OLS				PMG		
Exchange rate	0.400** (0.02)	0.416** (0.02)	0.448** (0.02)	0.480** (0.02)	0.400** (0.01)	0.430** (0.01)	0.427** (0.02)
Export price	0.337** (0.02)	0.328** (0.02)	0.330** (0.02)	0.324** (0.02)	0.195** (0.03)	0.206** (0.03)	0.212** (0.03)
China share *Exch. rate		0.025** (0.01)	-0.401** (0.12)	-0.945** (0.16)		-0.598** (0.13)	-0.618** (0.15)
China share			1.87** (0.55)	4.01** (0.68)			
Import tariff				-0.187 (0.12)			-0.159 (0.11)
China share *time				-0.017 (0.016)			
China share *(1-China share)				0.712** (0.17)			
Observations	2,905	2,905	2,905	2,905	2,634	2,634	2,634
R^2 or ϕ	0.641	0.642	0.644	0.647	ϕ=-0.17**	ϕ=-0.18**	ϕ=-0.18**
B. Consumer goods only (Enduse 4)							
	FE-OLS				PMG		
Exchange rate	0.331** (0.03)	0.363** (0.03)	0.476** (0.04)	0.536** (0.02)	0.350** (0.02)	0.465** (0.04)	0.466** (0.04)
Export Price	0.088** (0.03)	0.078* (0.03)	0.073* (0.03)	0.086** (0.03)	0.136** (0.04)	0.172** (0.04)	0.172** (0.04)
China share *Exch. rate		0.024* (0.01)	-0.583** (0.17)	-1.16** (0.20)		-0.730** (0.17)	-0.730** (0.17)
China share			2.68** (0.73)	4.81** (0.86)			
Import tariff				-0.544** (0.17)			0.002 (0.12)
China share *time				0.006 (0.017)			
China share *(1-China share)				0.958** (0.20)			
Observations	1,371	1,371	1,371	1,371	1,242	1,242	1,242
R^2 or ϕ	0.628	0.632	0.635	0.645	ϕ=-0.20**	ϕ=-0.21**	ϕ=-0.21**

Notes: * significant at 5%, ** significant at 1%; standard errors are in parentheses.
Regressions are run over 41 5-digit Enduse categories where no imports are covered by the Information Technology Agreement, from September 1993 – December 1999. OLS is estimated with 6 lags of the exchange rate, while 'pooled mean group' (PMG) is the maximum likelihood estimator for cointegrated panels, and chooses the lag length. All regressions include fixed effects for 5-digit Enduse categories.

Table 2: Numerical Simulation Results

(experiment: 10% rise in U.S. money supply, causing dollar depreciation)

	Pass-through under free entry	Pass-through under no entry	Mexican N_x	firms $\%\Delta N_x$	Chinese N_y	firms $\%\Delta N_y$
Benchmark case*	0.258	0.649	4.07	-4.1%	13.09	27.9%
Sensitivity analysis:						
$\beta = 0.85$	0.268	0.605	1.89	-3.4%	11.54	14.9%
$\gamma = 2$	0.129	0.669	3.11	-4.8%	7.36	37.6%
$\gamma = 5$	-0.149	0.700	2.19	-6.4%	3.39	55.9%
$\alpha_x = 0.7/20$, $\alpha_y = 0.3/20$	0.266	0.646	4.03	-4.1%	13.70	26.5%
Zero China share:	1.000	1.000	5.00	0%	0	-

* Benchmark calibration: $\beta = 0.5$, $\gamma = 1$, $f_x = 0.5$, $f_y = 0.005$, $\alpha_x = 0.9/20$, $\alpha_y = 0.1/20$, where 20 is the maximum number of differentiated products, $w_x = 1$, $w_y = 1$, which implies a China share equal to 0.25.

Table 3: Numerical Simulation of Alternative Chinese Exchange Rate Rules

(experiment: 10% rise in U.S. money supply, causing dollar depreciation)

Monetary policy parameter, ψ	$\%\Delta\, e_y/\%\Delta\, e_x$	Pass-through (free entry)
0	0	0.258
0.01	0.171	0.418
0.05	0.519	0.693
0.10	0.695	0.813
0.25	0.874	0.924
0.50	0.954	0.972
1.00	1.000	1.000

* Calibration: $\beta = 0.5$, $\gamma = 1$, $f_x = 0.5$, $f_y = 0.005$, $\alpha_x = 0.9/20$, $\alpha_y = 0.1/20$, where 20 is the maximum number of differentiated products, $w_x = 1$, $w_y = 1$, which implies a China share equal to 0.25.