Federal Reserve Bank of New York
Staff Reports

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Staff Report no. 251
April 2006

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Arm's-Length Transactions as a Source of Incomplete Cross-Border Transmission: The Case of Autos

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JEL classification: F1, F3, F4

Abstract

A growing share of international trade occurs through intra-firm transactions—those between domestic and foreign subsidiaries of a multinational firm. The difficulties associated with writing and enforcing a vertical contract compound when a product must cross a national border, and may explain the high rate of multinational trade across such borders. We show that this common cross-border organization of the firm may have implications for the well-documented incomplete transmission of shocks across borders. We present new evidence of a positive relationship between an industry's share of multinational trade and its rate of exchange rate pass-through to prices. We then develop a structural econometric model with both manufacturers and retailers to quantify how firms' organization of their activities across borders affects their pass-through of a foreign cost shock. We apply the model to data from the auto market. Counterfactual experiments show why cross-border transmission may be much higher for a multinational transaction than for an arm's-length transaction. In the structural model, firms' pass-through of foreign cost shocks is on average 29 percentage points lower in arm's-length transactions than in multinational transactions because the higher markups from a double optimization along the distribution chain create more opportunity for markup adjustment following a shock. Since arm's-length transactions account for about 60 percent of U.S. imports, this difference may explain up to 20 percent of the incomplete transmission of foreign-cost shocks to the United States in the aggregate.

Key words: exchange rates, pass-through, vertical contracts, cross-border transmission, multinationals, arm's-length transactions, real exchange rates, autos

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The authors thank Linda Goldberg, Aviv Nevo, and Maurice Obstfeld for comments. The views expressed in this paper are those of the authors and do not necessarily reflect the position of the Federal Reserve Bank of New York or the Federal Reserve System.

1 Introduction

More and more, multinational firms dominate international trade. The difficulties associated with writing and enforcing an arm's-length vertical contract compound when a product must cross a national border and may explain the high share of multinational trade.[1] This paper develops a framework to analyze how firms' organization affects their cross-border transmission of shocks.

Understanding the sources of incomplete cross-border transmission has important implications for industry and for the economy generally. Assumptions about these sources shape economists' policy recommendations on basic issues in international goods and financial markets. In keeping with the importance of the subject, there is a large theoretical literature on the implications of alternative sources of this incomplete transmission.[2] A nascent empirical literature has documented the sources of incomplete transmission in different settings, but often has been hampered by a lack of data.[3] Before macroeconomic models can grapple with the welfare implications of each of the sources of incomplete transmission, they need stylized facts from the microeconomic literature

[1] A cross-border contract is by definition a vertical contract between an upstream (foreign) and a downstream (domestic) firm. Anderson and Van Wincoop (2004) give an overview of the empirical trade literature on frictions associated with writing and enforcing cross-border contracts.

[2] See, for example, Betts and Devereux (2000), Corsetti and Dedola (2005), Devereux, Engel, and Tille (2003), Dixit (1989), Dornbusch (1987), Engel and Rogers (2001), Feenstra, Gagnon, and Knetter (1996), Froot and Klemperer (1989), Krugman (1987), Obstfeld and Rogoff (2001), Tille (2001), Yi (2003).

[3] See, for example, Goldberg and Verboven (2001), Betts and Kehoe (2005), Burstein, Neves, and Rebelo (2003), Campa and Goldberg (2005), and Evans (2003). There is little disaggregated evidence on the sources of incomplete transmission. Prices along the distribution chain, particularly import and wholesale prices, are typically unavailable. It is also difficult to obtain cost data amenable to comparison from foreign manufacturers.

about the relative importance of each.

This paper establishes several such stylized microeconomic facts. It is the first to examine empirically the relative importance of three factors – nontraded costs, markup adjustments, and the contractual relationship of manufacturers and retailers that determine the level of cross-border transmission. It has two goals: to document at the product level when shocks are transmitted across borders; and to identify the sources of incomplete transmission within the framework of a structural model that allows for variation in firm boundaries across national borders.

We study two types of vertical contracts empirically: multinational and arms-length. The counterfactual experiments confirm that pass-through is much higher in a vertically-integrated distribution chain (where all transactions are multinational) than in a vertically-disintegrated distribution chain (where all transactions are arm's-length). We define pass-through as the percent change in a firm's price for a given percent change in the dollar. Estimating exchange-rate pass-through is not a simple exercise. On average, following a 10-percent appreciation of the dollar, firms pass through 44 percent of a foreign-cost shock to their retail prices in a vertically-integrated distribution chain and only 16 percent in a vertically-disintegrated distribution chain, a 28 percentage-point difference.

Our empirical approach has two components: estimation and simulation. At the estimation stage, we estimate the demand parameters and then the traded and nontraded costs and markups of the retailers and manufacturers for each vertical-contractual model. To assess the overall impact of each vertical contractual form on firms' transmission be-

havior, we employ simulation. We compute the industry equilibrium that would emerge if the dollar appreciated for the arm's-length vertical contract, and compare it to the equilibrium that prevails when one firm, a multinational, controls pricing along the distribution chain. We interpret the differential response of prices across the two cases as a measure of the overall impact of the firms' cross-border organization on their transmission of shocks.

We address two literatures on the sources of local-currency price stability with very different modeling approaches. The empirical trade literature, most notably Goldberg and Verboven (2001) and Hellerstein (2005), attributes local-currency price inertia to a local-cost component and to firms' markup adjustments, but without considering the roles of different vertical contracts between manufacturers and retailers on their pass-through behavior. Papers in the international-finance literature, such as Burstein, Neves, and Rebelo (2003), Campa and Goldberg (2004), and Corsetti and Dedola (2005), attribute local-currency price stability to the share of local nontraded costs in final-goods prices but do not model markup adjustments by the firms that incur these costs, whether manufacturers or retailers. This study builds on this earlier work by modeling markup adjustments for firms at each stage of the distribution chain as in Villas-Boas (2005) and Hellerstein (2005). We are aware of only one other paper, Hellerstein (2006) on the beer market, that looks at the relationship between the boundaries of the firm and the transmission of shocks across national borders.

We study the auto market for several reasons. First, as manufactured goods' prices tend to exhibit dampened responses to foreign shocks in aggregate data, autos are an

appropriate choice to investigate the puzzling phenomenon of incomplete transmission. Second, trade in autos and auto parts is quite large for most countries, which gives our empirical results direct policy relevance. For example, trade in autos and auto parts makes up almost one quarter of U.S. goods imports in any given year. Third, we have a rich panel data set with monthly retail and wholesale transaction prices for 19 models from a number of manufacturers over a period of 26 months. It is unusual to observe both retail- and wholesale-price data for a single product. These data enable us to decompose the role of local nontraded costs in the incomplete transmission. We consider models from the luxury segment of the market as this enables us to estimate a very flexible demand system, a random-coefficients demand system, even with our sample's limited time span.

The framework outlined here can be used to analyze the incomplete transmission of various types of foreign-cost shocks, including a productivity shock, an imposition of a tariff or other trade barrier, a factor-price increase, or a change in the nominal exchange rate. For this study, we interpret foreign firms' marginal-cost shocks as caused by changes in the bilateral nominal exchange rate, so the cross-border transmission of shocks is equivalent to the pass-through of an exchange-rate shock to prices. The model assumes that foreign manufacturers incur marginal costs in their own currencies to manufacture and transport each auto to a U.S. port. They observe the realized value of the nominal exchange rate before setting prices in the domestic currency, and they assume that any exchange-rate change is exogenous and permanent over the sample

period of one month.[4] A key identification assumption is that, in the short run, nominal exchange-rate fluctuations dwarf other sources of variation in manufacturers' marginal costs, such as factor-price changes. This assumption, though strong, has clear support in the data.[5]

The next section presents some stylized facts about the relationship between exchange-rate pass-through and multinational trade, and section 3 presents a simple illustration to build intuition for the theoretical model. Section 4 sets out the theoretical model, section 5 discusses the market and the data and section 6 discusses the estimation methodology. Results from the random-coefficients demand model are reported in section 7, and those of the counterfactual experiments in section 8, and finally section 9 concludes.

2 Multinationals and Cross-Border Transmission

Roughly 40 percent of U.S. imports occur through intra-firm transactions, that is, transactions between domestic and foreign subsidiaries of a multinational firm. In this section, we present evidence of a positive relationship between an industry's share of multinational imports and its pass-through of exchange-rate-induced marginal-cost shocks to prices.

Exchange-rate pass-through is defined as the percent change in an industry's prices

[4] This assumption is consistent with the stylized fact identified by Meese and Rogoff (1983) that the best short-term forecast of the nominal exchange rate is a random walk.

[5] The breakdown of the Bretton-Woods fixed exchange-rate system in 1973 led to a permanent threefold to ninefold increase in nominal exchange-rate volatility. Meanwhile fundamentals such as real output, interest rates, or consumer prices showed no corresponding rise in volatility. While nominal exchange rates are now remarkably volatile, they ordinarily appear unconnected to the fundamentals of the economies whose currencies they price.

for a given percent change in the dollar. Estimating exchange-rate pass-through is not a simple exercise. The sensitivity of import prices to dollar movements may differ from a simple correlation between the two variables due to independent activity in the production or demand sectors. To estimate pass-through, one must control for other forces that affect firms' choices of import prices, such as demand conditions in the importing country and cost changes in the exporting country that should not be attributed to exchange-rate movements. Most pass-through models also recognize that there are sometimes delayed import-price responses to exchange-rate movements, and that these adjustments may take up to a year or longer.

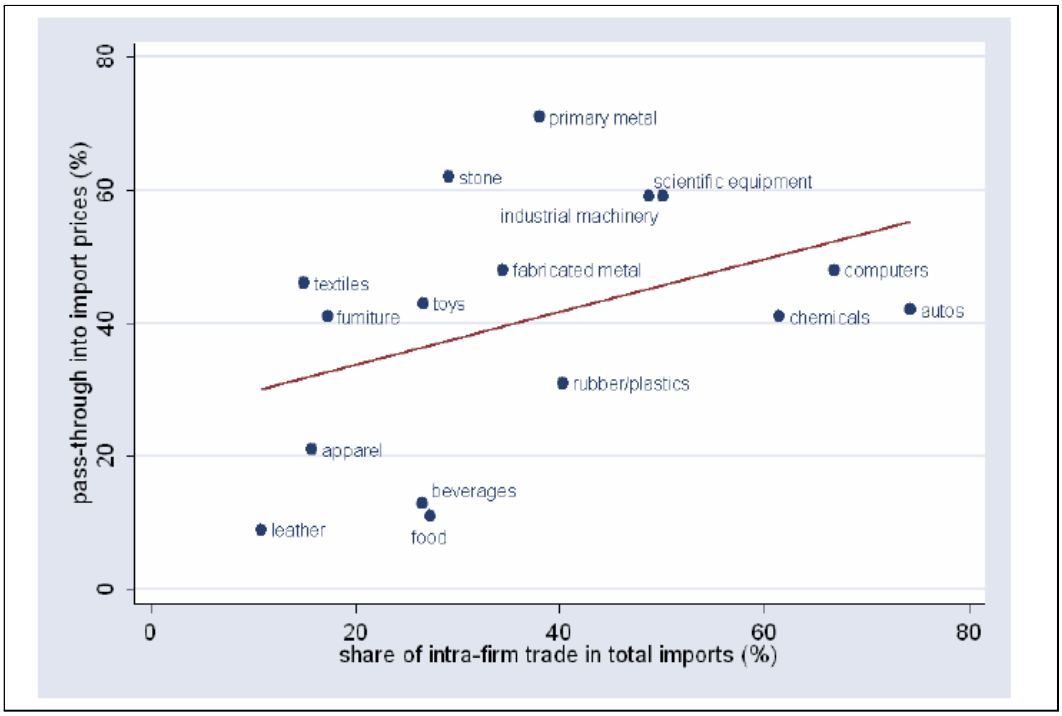


Figure 1: *Industries with High Multinational Trade Exhibit High Exchange-Rate Pass-Through.*

We use a standard workhorse model to estimate exchange-rate pass-through elasticities. Similar specifications are used in Feenstra (1989), Goldberg and Knetter (1997), and Campa and Goldberg (2005). Our pricing equation is:

$$p_t = \alpha + \sum_{i=0}^{4} a_i e_{t-i} + \sum_{j=0}^{4} b_j w_{t-j} + c_t Y_t + \varepsilon_t$$

where p_t is an index of U.S. import prices at time t, α is a constant, e_{t-i} is the import-weighted nominal exchange rate at time t minus i, w_{t-j} is a control for supply shocks that may affect import prices independently of the exchange rate at time t minus j, Y_t is a control for demand shifts that may affect import prices independently of the exchange rate at time t, and ε_t is an econometric error term. All the regressions use ordinary least squares. The nominal import-weighted exchange rates are constructed by the authors from the bilateral exchange rates of 34 currencies with the dollar, each weighted by its annual share in the industry's imports. The import-price indexes exclude petroleum imports and are from the U.S. National Accounts. The import-volume data are from the U.S. International Trade Commission. The domestic demand data are from the U.S. Commerce Department's Bureau of Economic Analysis. The regressions are run at the industry level with industry-specific import-price, nominal import-weighted exchange-rate, and import-weighted *CPI* and foreign-cost indexes. Exchange-rate pass-through is the sum of the coefficients on the nominal import-weighted exchange rate e at time t plus four lagged periods. Our model controls for foreign-cost shocks other than exchange-rate fluctuations with an import-weighted foreign consumer-price index (*CPI*). Although

foreign producer prices (*PPI*s) would be a better measure of foreign-cost shocks than are consumer prices, *CPI*s usually track changes in *PPI*s well, and *CPI*s are available over more countries and years. Changes in the demand for imports that reflect variation in consumer tastes or income rather than in the dollar's value are controlled for by including U.S. domestic demand in the regression. U.S. domestic demand is defined as U.S. total domestic output (*GDP*) minus exports (demand from outside the U.S.) plus imports (U.S. demand not satisfied by domestic output). Import prices are measured by an index of goods' prices upon entry into the U.S.

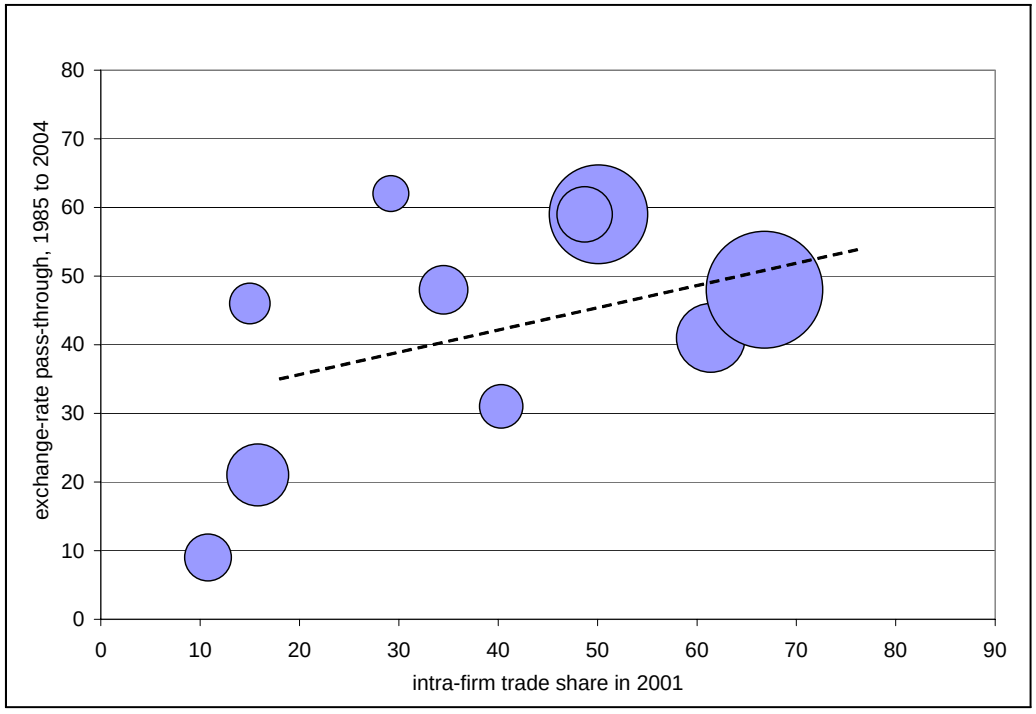


Figure 2: *Industries with High Multinational Trade Exhibit High Exchange-Rate Pass-Through.*

Figures 1 and 2 illustrate the positive relationship between the share of multinational

transactions in an industry's total imports, on the x-axes, and its estimated pass-through elasticity, on the y-axes. The multinational shares are from 2001, but as there is considerable inertia in these numbers, the results do not change if one uses an average of such shares over time. Figure 1 lists the names of the individual industries (defined by 3-digit *NAICS* code). Each industry has equal weight in the linear-trend computation in this figure, while Figure 2 weights each industry by its share of total U.S. imports. These weights are illustrated in Figure 2 by the size of the bubble at each industry's location in the scatterplot. The linear trend line in both figures is clearly upward sloping.

These figures illustrate a new stylized fact about cross-border transmission at the industry level, that it is positively related to the share of trade conducted through multinational affiliates. We use this stylized fact to motivate the exercises done with the structural model.

3 A Simple Numerical Exercise

To build intuition for the structural model presented in the next section, this section uses a simple numerical exercise to illustrate the importance of three sources of incomplete transmission: firms' local nontraded costs, markup adjustments, and vertical contractual relationships.

3.1 Arm's-Length Transactions

Figure 3 illustrates the stages of cross-border transmission in the structural model with an arm's-length vertical contract. The figure depicts what happens to a good's price as it moves from a factory gate, to an export port, to an import port, to a retailer, and finally, is purchased by a consumer. The exercise follows the price of a German auto as it travels from the factory gate to the consumer before and after a dollar depreciation.

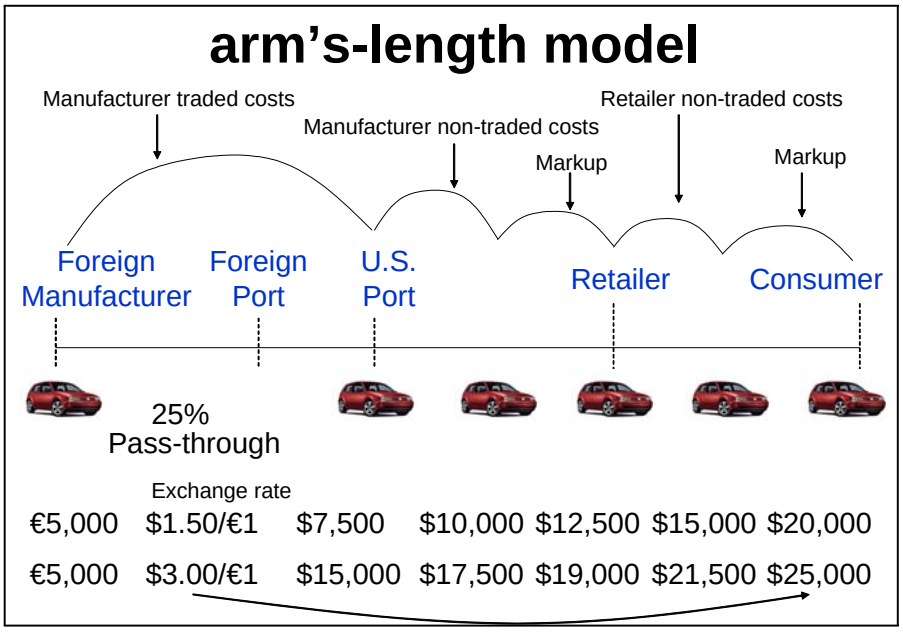


Figure 3: *Sources of Incomplete Transmission for the Arm's-Length Model.*

Suppose the manufacturer's cost to produce the auto and transport it to a U.S. port is €5000. At the U.S. border, the product's price begins to be denominated in dollars. The prevailing exchange rate is assumed to be \$1.50 dollars per euro, so the manufacturer's marginal cost in dollars is \$7500. The manufacturer incurs an additional \$2500 in local nontraded costs to get the product to the retailer and has a \$2500 markup. (A **markup**

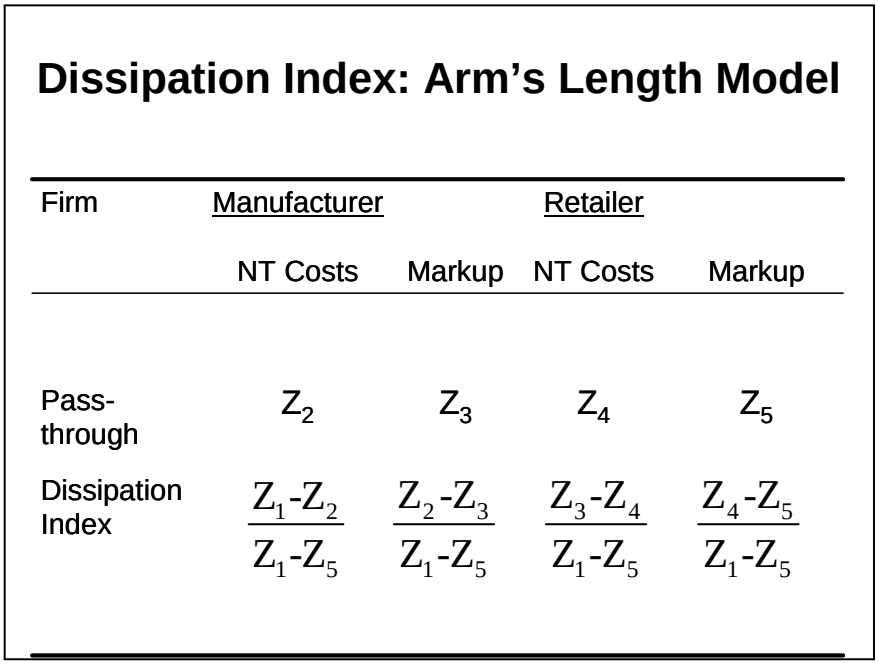


Figure 4: *Dissipation Index for the Arms-Length Model.* Z_1 denotes firms' pass-through to import prices at the U.S. dock. As we assume full pass-through at the dock, it is 100% in this figure.

is defined as a firm's price less its marginal cost. A **margin** is defined as a firm's price less its marginal cost, divided by its price.) The retailer incurs $2500 in nontraded costs in the form of rent, wages, and the like, and has a $5000 markup. The first line of prices under the figure summarizes this sequence.

The second line of prices shows what happens to the auto's price following a 100-percent dollar depreciation against the euro. The exchange rate is now $3 dollars per euro. While the cost in euros to produce the auto has not changed, its cost in dollars has doubled. For simplicity, we assume that the exchange-rate change is fully passed through at the dock, so the new import price is $15,000. **Manufacturer-nontraded pass-through** is defined as incomplete pass-through caused by the presence of local nontraded

costs incurred by a manufacturer in a good's price. The addition of the manufacturer's nontraded cost of $2500 produces a manufacturer nontraded pass-through elasticity of 75 percent. **Manufacturer-traded pass-through** is defined as the incomplete pass-through of the original shock to the wholesale price following a markup adjustment by the manufacturer. If, following the depreciation, the manufacturer's markup remained constant at $2500, its price would be $20,000, which implies 60-percent pass-through. If the manufacturer's margin remained constant at 25 percent, its price would be $21,900, and the manufacturer's traded pass-through would equal its nontraded pass-through of 75 percent. Its $19,000 price reflects a 52-percent pass-through of the original shock. **Retail-nontraded pass-through** is defined as the incomplete pass-through of the original shock to the retail price due to the presence of a local nontraded component in retail costs. The retailer's nontraded costs lower the pass-through rate further, from 52 percent to 43 percent. **Retail-traded pass-through** is defined as the incomplete pass-through of the original shock to the retail price following the retailer's markup adjustment. The retailer's original margin was 33 percent, and its original markup, $5000. If the retailer maintained a constant margin after the depreciation, its price would be $28,600, rather than the $25,000 we observe. The retailer's traded pass-through is 25 percent, and would have been 43 percent with no margin adjustment.

3.1.1 Decomposition

The pass-through of the original exchange-rate shock to the retail price is, thus, 25 percent. This leaves 75 percent of the original shock to account for in the decomposition.

Figure 4 illustrates how the decomposition is computed. The first line of the table identifies Z_2, Z_3, Z_4, and Z_5 as manufacturer-nontraded pass-through, manufacturer-traded pass-through, retailer nontraded pass-through, and retailer traded pass-through, respectively. Z_1 denotes firms' pass-through to import prices at the U.S. dock. As we assume full pass-through at the dock, it is 100% in Figure 3. The second line of the illustration shows how to quantify an exchange-rate shock's incomplete transmission at each stage along the distribution chain using the dissipation index discussed in more detail in Hellerstein (2006). The table's first column computes the share of the incomplete transmission explained by the presence of a local component in the manufacturer's marginal costs. The second column computes the share of the incomplete transmission explained by the manufacturer's markup adjustment. The third column computes the share of the incomplete transmission explained by the presence of a local component in the retailer's costs, and the last column, the share of the incomplete transmission explained by the retailer's markup adjustment.

If one applies these formulas to the numbers in Figure 3, one finds that roughly 25 percentage points (33 percent) of this 75-percent incomplete transmission can be attributed to the presence of local nontraded costs in the manufacturer's price. This component brings pass-through down to 75 percent, from 100 percent at the dock. The decline in pass-through from 75 to 52 percent following the manufacturer's margin adjustment accounts for another 31 percent of the incomplete transmission. The decline in pass-through from 52 to 43 percent from the retailer's nontraded costs eats up another 12 percent of the 75 percent. And the decline in pass-through from 43 to 25 percent follow-

ing the retailer's margin adjustment accounts for the final 24 percent of the incomplete transmission.

3.2 Multinational Transactions

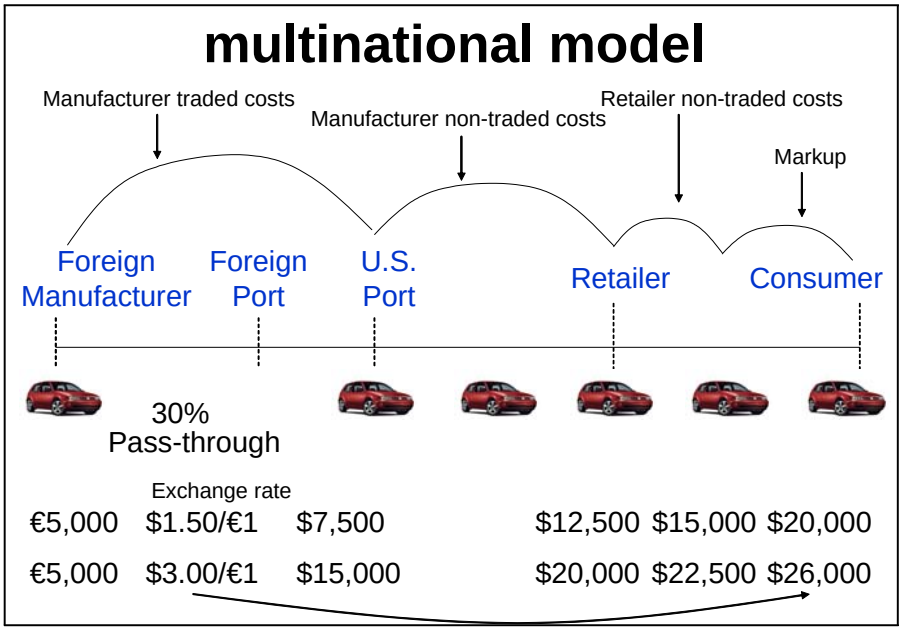


Figure 5: *Sources of Incomplete Transmission for the Multinational Model.*

Figure 5 illustrates the stages of cross-border transmission for the multinational model. The manufacturer's cost to produce the auto and transport it to a U.S. port remains €5000. At the U.S. border, the product's price begins to be denominated in dollars with an initial exchange rate of $1.50 dollars per euro, so the manufacturer's marginal cost in dollars is $7500. The manufacturer incurs an additional $5000 in local nontraded costs to get the product to the retailer, the retailer incurs $2500 in nontraded costs in the form of rent, wages, and the like, and has a $5000 markup. The first line of

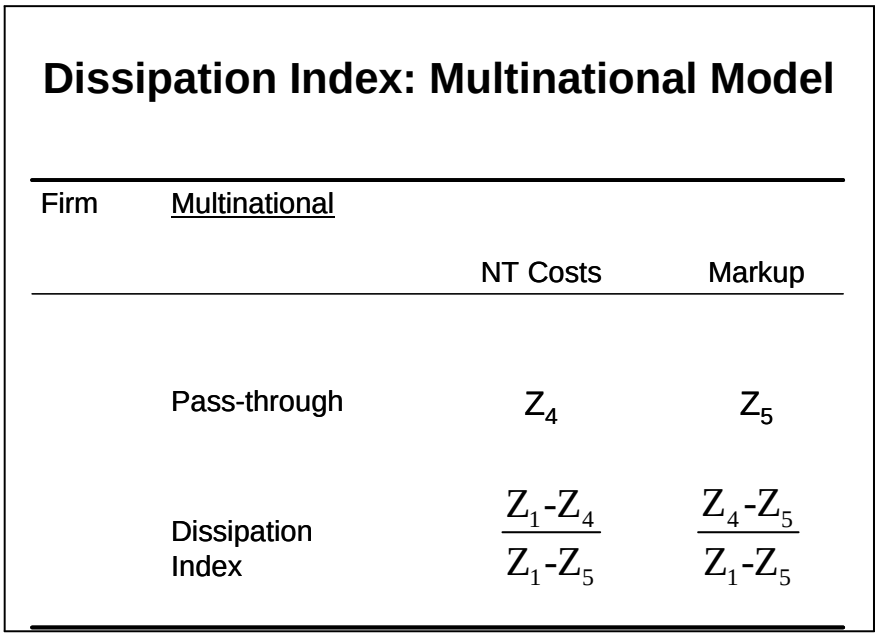


Figure 6: *Dissipation Index for the Multinational Model.* Z_1 denotes firms' pass-through to import prices at the U.S. dock. As we assume full pass-through at the dock, it is 100% in this figure.

prices under the figure summarizes this sequence.

The second line of prices shows what happens to the auto's price following a 100-percent dollar depreciation against the euro. The exchange rate is now \$3 dollars per euro, so the new import price is \$15,000. The addition of the manufacturer's nontraded cost of \$5000 produces a manufacturer nontraded pass-through elasticity of 60 percent. The retailer's nontraded costs lower the pass-through rate further to 50 percent. The retailer's traded pass-through is 30 percent, and would have been 50 percent with no margin adjustment.

3.2.1 Decomposition

The pass-through of the original exchange-rate shock to the retail price is, thus, 30 percent in the multinational scenario. This leaves 70 percent of the original shock to account for in the decomposition. Figure 6 illustrates how the decomposition is computed for the multinational model. The first line of the table identifies Z_4 and Z_5 as the multinational's nontraded pass-through and its traded pass-through, respectively. Z_1 denotes its pass-through to import prices at the U.S. dock. As we assume full pass-through at the dock, it is 100% in this figure. The second line of the table shows how an exchange-rate shock is incompletely transmitted at each stage along the distribution chain using a variant of the dissipation index in Hellerstein (2006). The table's first column computes the share of the incomplete transmission explained by the presence of a local component in the multinational's marginal costs. The second column computes the share of the incomplete transmission explained by the multinational's markup adjustment.

If one applies this formula to the numbers in Figure 5, one finds that roughly 40 percentage points (57 percent) of this 70-percent incomplete transmission can be attributed to the presence of local nontraded costs in the manufacturer's price. This component brings pass-through down to 60 percent, from 100 percent at the dock. The decline in pass-through from 60 to 50 percent from the retailer's nontraded costs eats up another 10 percentage points (14 percent) of the 70 percent. And the decline in pass-through from 50 to 30 percent following the retailer's margin adjustment accounts for the final 20 percentage points (29 percent) of the incomplete transmission.

To summarize, this section has presented two simple exercises to illustrate the various sources of cross-border transmission. The next section sets out a model that formalizes the role of each of these sources in firms' incomplete transmission.

4 Model

This section describes the vertical supply models used in the analysis and derives simple expressions to compute transmission coefficients and to decompose the sources of local-currency price rigidity between the nontraded costs and markup adjustments of manufacturers and retailers. It shows how the degree of markup adjustment is determined by the vertical contract between each manufacturer-retailer pair. It then sets out the random-coefficients model used to estimate demand.

4.1 Supply

This section introduces the two vertical supply models we consider.

4.2 Arm's-Length Model

Consider a standard linear-pricing model in which manufacturers, acting as Bertrand oligopolists with differentiated products, set their prices followed by retailers who set their prices taking the wholesale prices they observe as given. Thus, a double markup is added to the marginal cost to produce the product. Strategic interactions between manufacturers and retailers with respect to prices follow a sequential Nash-Bertrand model. To solve the model, one uses backwards induction and solves the retailer's problem first.

4.2.1 Retailers

Consider R retail firms that each sell some share κ^r of the market's J differentiated products. Let all firms use linear pricing and face constant marginal costs. The profits of a retail firm in market t are given by:

$$\Pi^r_{jt} = \sum_{j \in \kappa^r} \left(p^r_{jt} - p^w_{jt} - ntc^r_{jt}\right) s_{jt}(p^r_t) \tag{1}$$

where p^r_{jt} is the price the retailer sets for product j, p^w_{jt} is the wholesale price paid by the retailer for product j, ntc^r_{jt} are local nontraded costs paid by the retailer to sell product j, and $s_{jt}(p^r_t)$ is the quantity demanded (or market share) of product j which is a function

of the prices of all J products. Assuming that each retailer acts as a Nash-Bertrand profit maximizer, the retail price p_{jt}^r must satisfy the first-order profit-maximizing conditions:

$$s_{jt} + \sum_{k \in \kappa^r} (p_{kt}^r - p_{kt}^w - ntc_{kt}^r) \frac{\partial s_{kt}}{\partial p_{jt}^r} = 0, \text{ for } j = 1, 2, ..., J_t. \tag{2}$$

This gives us a set of J equations, one for each product. One can solve for the markups by defining $S_{jk} = \frac{\partial s_{kt}(p_t^r)}{\partial p_{jt}^r} \quad j, k = 1, ..., J.$, as the matrix of retail demand substitution patterns, the marginal change in the kth product's market share given a change in the jth product's retail price, and a $J \times J$ matrix Ω_{rt} with the (jth, kth) element equal to S_{jk} if both products j and k are sold by the same retailer, and equal to zero if not sold by the same retailer. The stacked first-order conditions can be rewritten in vector notation:

$$s_t + \Omega_{rt}(p_t^r - p_t^w - ntc_t^r) = 0 \tag{3}$$

and inverted together in each market to get the retailer's pricing equation, in vector notation:

$$p_t^r = p_t^w + ntc_t^r - \Omega_{rt}^{-1} s_t \tag{4}$$

where the retail price for product j in market t will be the sum of its wholesale price, nontraded costs, and markup.

4.2.2 Manufacturers

Let there be M manufacturers that each produce some subset Γ_{mt} of the market's J_t differentiated products. Each manufacturer chooses its wholesale price p_{jt}^w while assuming each retailer behaves according to its first-order condition (2). Manufacturer w's profit function is:

$$\Pi_t^w = \sum_{j \in \Gamma_{mt}} \left(p_{jt}^w - tc_{jt}^w - ntc_{jt}^w\right) s_{jt}(p_t^r\left(p_t^w\right)) \tag{5}$$

where tc_{jt}^w are traded costs and ntc_{jt}^w are destination-market nontraded costs incurred by the manufacturer to produce and sell product j.[6] Multiproduct manufacturing firms are represented by a manufacturer ownership matrix, T_w, with elements $T_w\left(j,k\right) = 1$ if both products j and k are produced by the same manufacturer, and zero otherwise. Assuming a Bertrand-Nash equilibrium in prices and that all manufacturers act as profit maximizers, the wholesale price p_{jt}^w must satisfy the first-order profit-maximizing conditions:

$$s_{jt} + \sum_{k \in \Gamma_{mt}} T_w\left(k,j\right)\left(p_{kt}^w - tc_{kt}^w - ntc_{kt}^w\right)\frac{\partial s_{kt}}{\partial p_{jt}^w} = 0 \text{ for } j = 1,2,...,J_t. \tag{6}$$

This gives us another set of J equations, one for each product. Let S_{wt} be the matrix with elements $\frac{\partial s_{kt}(p_t^r(p_t^w))}{\partial p_{jt}^w}$, the change in each product's share with respect to a change in

[6] Nontraded costs incurred by the manufacturer in its home country are treated as part of its traded costs. As such nontraded costs will be denominated in the home country's currency, they will be subject to shocks caused by variation in the nominal exchange rate while nontraded costs incurred in the destination market will not.

each product's wholesale price (or also alternatively to the traded marginal cost to the manufacturer). This matrix is a transformation of the retailer's substitution patterns matrix previously defined: $S_{wt} = S'_{pt} S_{rt}$ where S_{pt} is a J-by-J matrix of the partial derivative of each retail price with respect to each product's wholesale price. Each column of S_{pt} contains the entries of a response matrix computed without observing the retailer's marginal costs. The properties of this manufacturer response matrix are described in greater detail in Villas-Boas (2005) and Villas-Boas and Hellerstein (2006). To obtain expressions for this matrix, one uses the implicit-function theorem to totally differentiate the retailer's first-order condition for product j with respect to all retail prices ($dp_k^r,\ k = 1, .., N$) and with respect to the manufacturer's price p_f^w with variation dp_f^w :

(7)

$$\sum_{k=1}^{N} \underbrace{\left(\frac{\partial s_j}{\partial p_k^r} + \sum_{i=1}^{N} \left(T_r(i,j) \frac{\partial^2 s_i}{\partial p_j^r \partial p_k^r} \left(p_i^r - p_i^w - c_i^r - n t c_i^w - t c_i^w \right) \right) + T_r(k,j) \frac{\partial s_k}{\partial p_j^r} \right)}_{v(j,k)} dp_k^r - \underbrace{T_r(f,j) \frac{\partial s_f}{\partial p_j^r}}_{w(j,f)} dp_f^w$$

Let V be a matrix with general element $v(j,k)$ and W be an N-dimensional vector with general element $w(j,f)$. Then $V dp^r - W_f dp_f^w = 0$. One can solve for the derivatives of all retail prices with respect to the manufacturer's price f for the fth column of Λ_w :

$$\frac{dp^r}{dp_f^w} = V^{-1} W_{f.}$$

Stacking the N columns together gives $S_p = V^{-1} W_f$ which gives the derivatives of all retail prices with respect to all manufacturer prices, with general element: $S_p(i,j) = \frac{dp_j^r}{dp_i^w}$.

The (jth, kth) entry in S_{pt} is then the partial derivative of the kth product's retail price with respect to the jth product's wholesale price for that market. The (jth, kth) element of S_{wt} is the sum of the effect of the jth product's retail marginal costs on each of the J products' retail prices which in turn each affect the kth product's retail market share, that is: $\sum_m \frac{\partial s_{kt}}{\partial p^r_{mt}} \frac{\partial p^r_{mt}}{\partial p^w_{jt}}$ for $m = 1, 2, ...J$.

The manufacturers' marginal costs are then recovered by inverting the element by element multiplication of $S_{wt} * T_w$ for each market t, in vector notation, where the (j,k) element of T_w is equal to one if both products j and k are sold by the same manufacturer and equal to zero if not. So

$$p^w_t = tc^w_t + ntc^w_t - (S_{wt} * T_w)^{-1} s_t \tag{8}$$

where for product j in market t the wholesale price is the sum of the manufacturer traded costs, nontraded costs, and markup function. The manufacturer of product j can use its estimate of the retailer's nontraded costs and reaction function to compute how a change in the manufacturer price will affect the retailer price for its product. Manufacturers can assess the impact on the vertical profit, the size of the pie, as well as its share of the pie by considering the retailer reaction function before choosing a price. Manufacturers may also act strategically with respect to one another. The retailer mediates these interactions by its transmission of a given manufacturer's price change to the product's retail price. Manufacturers set prices after considering the nontraded costs the retailer must incur, the retailer's transmission of any manufacturer price changes to the retail

price, and other manufacturers' and consumers' reactions to any retail-price changes.

4.3 Deriving Manufacturer Pass-Through of Traded Costs

To recover transmission coefficients we estimate the effect of a shock to foreign firms' marginal costs on all firms' wholesale and retail prices by computing a new Bertrand-Nash equilibrium. Suppose a shock hits the traded component of the jth product's marginal cost. To compute the manufacturer transmission, one substitutes the new vector of traded marginal costs, tc_t^{w*}, into the system of J nonlinear equations that characterize manufacturer pricing behavior, and then searches for the wholesale price vector p_t^{w*} that will solve the system in each market t:

$$p_{jt}^{w*} = tc_{jt}^{w*} + ntc_{jt}^{w} - \sum_{k \in \Gamma_{mt}} \left(S_{wt} * T_w\right)^{-1} s_{kt} \text{ for } j = 1, 2, ..., J_t. \tag{9}$$

To get an expression for the derivatives of all manufacturer prices with respect to all manufacturer traded marginal cost, defined as the matrix Λ_{tcw} with general element $\Lambda_{tcw}(i,j) = \frac{\partial p_j^w}{\partial tc_i^w}$, we totally differentiate the manufacturer's first-order condition for product j with respect to all manufacturer prices $(dp_k^w,\ k = 1, .., N)$ and with respect to the traded marginal cost tc_f^w with variation dtc_f^w :

$$\sum_{k=1}^{N} \underbrace{\left(\frac{\partial s_j}{\partial p_k^w} + \sum_{i=1}^{N} \left(T_w(i,j) \frac{\partial^2 s_i}{\partial p_j^w \partial p_k^w} \left(p_i^w - ntc_i^w - tc_i^w\right) \right) + T_w(k,j) \frac{\partial s_k}{\partial p_j^w} \right)}_{y(j,k)} dp_k^w - \underbrace{T_w(f,j) \frac{\partial s_f}{\partial p_j^w}}_{z(j,f)} dtc_f^w \tag{10}$$

Let Y be a matrix with general element $y(j,k)$ and Z be an N-dimensional vector with general element $z(j,f)$. Then $Ydp^w - Z_f dtc_f^w = 0$. One can solve for the derivatives of all wholesale prices with respect to the traded marginal cost f for the fth column of Λ_{tcw} :

$$\frac{dp^w}{dtc_f^w} = Y^{-1}Z_{f.}$$

Stacking the N columns together gives the matrix $\Lambda_{tcw} = Y^{-1}Z$ which computes the derivatives of all manufacturer prices with respect to all manufacturer traded marginal costs, with general element: $\Lambda_{tcw}(i,j) = \frac{dp_j^w}{dtc_i^w}$.

4.4 Deriving Retail Pass-Through

To compute transmission at the retail level, one substitutes the derived values of the vector p_t^{w*} into the system of J nonlinear equations for the retail firms, and then searches for the retail price vector p_t^{r*} that will solve it:

$$p_{jt}^{r*} = p_{jt}^{w*} + ntc_{jt}^r - \sum_{k \in \kappa^r} (S_{wt} * T_w)^{-1} s_{kt} \text{ for } j,k = 1,2,...,J_t. \tag{11}$$

To get an expression for the derivatives of all retail prices with respect to all originally changing manufacturer traded marginal costs, defined as the the matrix Λ_{tcr} with general element $\Lambda_{tcr}(i,j) = \frac{\partial p_j^r}{\partial tc_i^w}$, one must first calculate $\frac{\partial p_j^r}{\partial p_i^w}$, as described in the previous section. Retail-traded transmission, defined as transmission of the original marginal-cost shock to the retail price, is given by $\left(\frac{dp^r}{dp_f^w}\right)' \frac{dp^w}{dtc_f^w}$.

4.5 Multinational Model

We consider the multinational model of vertically integrated firms where in these intra-firm vertical relationships we observe zero retail margins and manufacturer pricing decisions in the equilibrium.[7]

In this model retailers add only retail costs to the wholesale prices, i.e. $p_{jt} = p_{jt}^w + c_{jt}^r$ for all j. The manufacturers' implied price-cost margins are given by, in vector notation:

$$p^w - ntc - tc^w = -\left[S_{wt} * T_w\right]^{-1} s(p) \tag{12}$$

It is worth noting that the implied price-cost margins in equation (12) are different from those implied by equation (4) because manufacturers and retailers are maximizing their profits over a different set of products. In Berry, Levinsohn and Pakes (1995) and Nevo (2001), the (manufacturer) implied price-cost margins computed are given by expressions similar to (12), and the retailers' decisions are not modeled.

The equilibrium prices after shock are given by the vector p_t^{w*} that solves:

$$p_t^{w*} = tc_t^{w*} + ntc_t - \left(S_{wt}^* * T_w\right)^{-1} s_t^* \tag{13}$$

[7]Note that, alternatively one could interpret this model as inter-firm (arms-length) vertical relationships with the use of non-linear-pricing contracts, where we observe zero retail margins and manufacturer pricing decisions in the equilibrium. This outcome arises, as shown in Rey and Vergé (2004), in the situation where retailers have all the bargaining power and make take-it-or-leave-it offers to manufacturers.

Retail pass-through is 100 percent, and the retail-traded pass-through is equal to the manufacturer traded pass-through in the previous section.

4.6 Illustration: Single Product Manufacturers and Retailers

To build intuition, we derive next expressions for pass-through for the arm's-length and the multinational models. In particular we shall derive expressions for $\frac{dp^w}{dtc_f^w}$, $\frac{dp^r}{dp_f^w}$, and $\left(\frac{dp^r}{dp_f^w}\right)' \frac{dp^w}{dtc_f^w}$ for a simple model with single-product firms. Consider first the an arm's-length case of single-product manufacturers each selling to single-product retailers. One can compute product j's wholesale transmission elasticity and transmission rate by using the implicit-function theorem to take the total derivative of p_{jt}^w with respect to tc_{jt}^w and rearranging terms:

$$\frac{dp_{jt}^w}{dtc_{jt}^w} = \frac{1}{2 - \frac{s_{jt}}{\frac{\partial s_{jt}}{\partial p_{jt}^w}} \frac{\frac{d^2 s}{\partial p_{jt}^{w2}}}{\frac{\partial s_{jt}}{\partial p_{jt}^w}}} = \frac{1}{2 + \text{markup} \cdot \text{curvature coefficient}} \tag{14}$$

$$\frac{dp_{jt}^w}{dtc_{jt}^w} \frac{tc_{jt}^w}{p_{jt}^w} = \frac{1}{\left(2 - \frac{s_{jt}}{\frac{\partial s_{jt}}{\partial p_{jt}^w}} \frac{\frac{d^2 s}{\partial p_{jt}^{w2}}}{\frac{\partial s_{jt}}{\partial p_{jt}^w}}\right) \frac{p_{jt}^w}{tc_{jt}^w}} = \frac{1}{(2 + \text{markup} \cdot \text{curvature coefficient}\ ) \frac{p_{jt}^w}{tc_{jt}^w}} \tag{15}$$

The wholesale transmission rate is given by: $PT^w = \frac{\left(p_{jt}^{w*} - p_{jt}^w\right)}{p_{jt}^{w*} + p_{jt}^w} \cdot \frac{tc_{jt}^{w*} + tc_{jt}^w}{tc_{jt}^{w*} - tc_{jt}^w}$. Equation (15) shows that it is determined by the jth good's markup, that is, its market share s_{jt} divided by the positive value of the slope of the derived demand curve with respect

to the wholesale price, $-\frac{\partial s_{jt}}{\partial p_{jt}^w}$, the curvature of the derived demand curve with respect to the wholesale price, summarized by the curvature coefficient, $-\frac{\frac{d^2 s}{\partial p_{jt}^{w2}}}{\frac{\partial s_{jt}}{\partial p_{jt}^w}}$, and the ratio of the manufacturer's wholesale price to the traded component of its marginal cost, $\frac{p_{jt}^w}{tc_{jt}^w}$. When derived demand is linear, so $\frac{d^2 s}{\partial p_{jt}^{w2}} = 0$, then $\frac{\partial p_{jt}^w}{\partial tc_{jt}^w} = \frac{1}{2}$ and transmission is: $\frac{\frac{\partial p_{jt}^w}{p_{jt}^w}}{\frac{\partial tc_{jt}^w}{tc_{jt}^w}} = \frac{1}{2\frac{p_{jt}^w}{tc_{jt}^w}}$. When the derived demand curve is less concave than the linear case so $\frac{d^2 s}{\partial p_{jt}^{w2}} > 0$, $\frac{\partial p_{jt}^w}{\partial tc_{jt}^w} > \frac{1}{2}$, manufacturer transmission rises: $\frac{\frac{\partial p_{jt}^w}{p_{jt}^w}}{\frac{\partial tc_{jt}^w}{tc_{jt}^w}} > \frac{1}{2\frac{p_{jt}^w}{tc_{jt}^w}}$. When the derived demand curve is more concave than the linear case so $\frac{d^2 s}{\partial p_{jt}^{w2}} < 0$, $\frac{\partial p_{jt}^w}{\partial tc_{jt}^w} < \frac{1}{2}$, manufacturer transmission falls: $\frac{\frac{\partial p_{jt}^w}{p_{jt}^w}}{\frac{\partial tc_{jt}^w}{tc_{jt}^w}} < \frac{1}{2\frac{p_{jt}^w}{tc_{jt}^w}}$. As the ratio of the product's wholesale price to its traded marginal costs rises, manufacturer transmission also falls. As a product's curvature coefficient or its markup rises, manufacturer transmission falls if the second derivative is negative, as is the standard case. As a product's market share rises, the manufacturer's traded transmission elasticity rises.

Assuming the retailer's nontraded marginal costs ntc_{jt}^r vary independently of the wholesale price, the change in product j's retail price for a given change in its wholesale price is:

$$\frac{dp_{jt}^r}{dp_{jt}^w} = \frac{1}{2 - \frac{s_t}{\frac{\partial s_{jt}}{\partial p_{jt}}} \frac{\frac{d^2 s_t}{\partial p_{jt}}}{\frac{\partial s_{jt}}{\partial p_{jt}}}} = \frac{1}{2 + \text{markup} \cdot \text{curvature coefficient}} \tag{16}$$

$$(17) \qquad \frac{dp^r_{jt}}{dp^w_{jt}}\frac{p^w_{jt}}{p^r_{jt}} = \frac{1}{\left(2 - \frac{s_t}{\frac{\partial s_{jt}}{\partial p_{jt}}}\frac{\frac{d^2 s_t}{\partial p_{jt}}}{\frac{\partial s_{jt}}{\partial p_{jt}}}\right)\frac{p^r_{jt}}{p^w_{jt}}} = \frac{1}{(2 + \text{markup} \cdot \text{curvature coefficient})\frac{p^r_{jt}}{p^w_{jt}}}$$

Retail transmission, defined as transmission by the retailer of just those costs passed on by the manufacturer is: $PT^R = \frac{p^{r*}_{jt} - p^r_{jt}}{p^{r*}_{jt} + p^r_{jt}} \frac{p^{w*}_{jt} + p^w_{jt}}{p^{w*}_{jt} - p^w_{jt}}$. Equation (17) shows that it is determined by the jth good's markup, that is, its market share s_{jt} divided by the positive value of the slope of the demand curve with respect to the retail price, $-\frac{\partial s_{jt}}{\partial p^r_{jt}}$, the curvature of the demand curve with respect to the retail price, summarized by the curvature coefficient, $-\frac{\frac{d^2 s_t}{\partial p_{jt}}}{\frac{\partial s_{jt}}{\partial p_{jt}}}$, and the ratio of the retailer's price to the manufacturer's price, $\frac{p^r_{jt}}{p^w_{jt}}$ .When demand is linear, so $\frac{d^2 s_t}{\partial p_{jt}} = 0$, then $\frac{\partial p^w_{jt}}{\partial p^w_{jt}} = \frac{1}{2}$; $\frac{dp^r_{jt}}{dp^w_{jt}}\frac{p^w_{jt}}{p^r_{jt}} = \frac{1}{2\frac{p^r_{jt}}{p^w_{jt}}}$. When the demand curve is more concave than the linear case so $\frac{d^2 s}{\partial p^{r2}_{jt}} < 0$, then $\frac{p^r_{jt}}{p^w_{jt}} < \frac{1}{2}$, retail transmission falls: $\frac{dp^r_{jt}}{dp^w_{jt}}\frac{p^w_{jt}}{p^r_{jt}} < \frac{1}{2\frac{p^r_{jt}}{p^w_{jt}}}$. As the markup or the curvature coefficient rises, transmission falls if the second derivative is negative. As the ratio of the retail price to the manufacturer price $\frac{p^r_{jt}}{p^w_{jt}}$ rises, transmission falls. Finally, retail traded-goods transmission, defined as transmission of the original marginal-cost shock to the retail price is $PT^R = \frac{p^{r*}_{jt} - p^r_{jt}}{p^{r*}_{jt} + p^r_{jt}} \cdot \frac{tc^{w*}_{jt} + tc^w_{jt}}{tc^{w*}_{jt} - tc^w_{jt}}$. It is given by $\left(\frac{dp^r}{dp^w_f}\right)' \frac{dp^w}{dtc^w_f}$.

For the multinational model, the retail traded-goods transmission is computed exactly as in the arm's-length model. The determinants of this transmission rate are the same as those identified in equation (15) with one importance modification, that retail transmission is complete, and therefore, irrelevant to understand incomplete transmis-

sion. As with the arm's-length model, in the multinational model the pass-through of the original shock to the retail price rises with the firm's markup or the curvature coefficient of demand if demand's second derivative is negative, and falls with the markup or curvature coefficient if demand's second derivative is positive. An extension of this simple model with multiproduct firms produces expressions for the determinants of transmission that differ only because of multiproduct firms' consideration when making pricing decisions of the cross-price elasticities between their products.

Several implications of this section's theoretical model can be tested to see if they are supported by the data. If the second derivative of demand is negative, $\frac{d^2 s}{\partial p_{jt}^{w2}} < 0$, as should be the case with utility-maximizing consumers, then across products: first, as manufacturer markups rise, manufacturer traded transmission rate PT^w should fall; second, as retail markups rise, retail traded transmission rate PT^R should fall; and finally, as a product's market share rises, manufacturer and retailer traded transmission rates also should rise. Recent work by Hellerstein and Villas-Boas (2006) discusses in greater depth how pass-through depends on the curvature of the demand curve in general and the implications of this for the use of various demand models, including the logit and the random-coefficients models, to do pass-through analysis.

4.7 Demand

The transmission computations done with the sequential Bertrand-Nash supply models require consistent estimates of demand. Market demand is derived from a stan-

dard discrete-choice model of consumer behavior that follows the work of Berry (1994), Berry, Levinsohn, and Pakes (1995), and Nevo (2001) among others. We use a random-coefficients logit model to estimate the demand system, as it is a very flexible and general model. The transmission coefficients' accuracy depends in particular on consistent estimation of the curvature of the demand curve (see Hellerstein and Villas-Boas, 2006), that is, of the second derivative of the demand equation. The random-coefficients model imposes very few restrictions on the demand system's own- and cross-price elasticities. This flexibility makes it the most appropriate model to study transmission in this market.

Suppose consumer i chooses to purchase one unit of good j if and only if the utility from consuming that good is as great as the utility from consuming any other good. Consumer utility depends on product characteristics and individual taste parameters. Product-level market shares are derived as the aggregate outcome of individual consumer decisions. All the parameters of the demand system can be estimated from product-level data, that is, from product prices, quantities, and characteristics.

Suppose we observe $t=1, ..., T$ markets. Let the indirect utility for consumer i in consuming product j in market t take a linear form:

$$(18) \qquad u_{ijt} = x_{jt}\beta_i - \alpha_i p_{jt} + \xi_{jt} + \varepsilon_{ijt}, \quad i = 1, ..., I., \quad j = 1, ..., J., \quad t = 1, ..., T.$$

where ε_{ijt} is a mean-zero stochastic term. A consumer's utility from consuming a given product is a function of product characteristics (x, ξ, p) where p are product prices, x are product characteristics observed by the econometrician, the consumer, and the

producer, and ξ are product characteristics observed by the producer and consumer but not by the econometrician. Let the taste for certain product characteristics vary with individual consumer characteristics:

$$\begin{pmatrix}\alpha_i \\ \beta_i\end{pmatrix} = \begin{pmatrix}\alpha \\ \beta\end{pmatrix} + \Pi D_i + \Sigma v_i \tag{19}$$

where D_i is a vector of demographics for consumer i, Π is a matrix of coefficients that characterize how consumer tastes vary with demographics, v_i is a vector of unobserved characteristics for consumer i, and Σ is a matrix of coefficients that characterizes how consumer tastes vary with their unobserved characteristics. We assume that, conditional on demographics, the distribution of consumers' unobserved characteristics is multivariate normal. The demographic draws give an empirical distribution for the observed consumer characteristics D_i. Indirect utility can be redefined in terms of mean utility $\delta_{jt} = \beta x_{jt} - \alpha p_{jt} + \xi_{jt}$ and deviations (in vector notation) from that mean $\mu_{ijt} = [\Pi D_i \ \Sigma v_i] * [p_{jt} \quad x_{jt}]$:

$$u_{ijt} = \delta_{jt} + \mu_{ijt} + \varepsilon_{ijt} \tag{20}$$

Finally, consumers have the option of an outside good. Consumer i can choose not to purchase one of the products in the sample. The price of the outside good is assumed to be set independently of the prices observed in the sample. The mean utility of the

outside good is normalized to be zero and constant over markets. The indirect utility from choosing to consume the outside good is:

$$u_{i0t} = \xi_{0t} + \pi_0 D_i + \sigma_0 v_{i0} + \varepsilon_{i0t} \tag{21}$$

Let A_j be the set of consumer traits that induce purchase of good j. The market share of good j in market t is given by the probability that product j is chosen:

$$s_{jt} = \int_{\zeta \in A_j} P^*(d\zeta) \tag{22}$$

where $P^*(d\zeta)$ is the density of consumer characteristics $\zeta = [D \quad \nu]$ in the population. To compute this integral, one must make assumptions about the distribution of consumer characteristics. We report estimates from two models. For diagnostic purposes, we initially restrict heterogeneity in consumer tastes to enter only through the random shock ε_{ijt} which is independently and identically distributed with a Type-I extreme-value distribution. For this model, the probability of individual i purchasing product j in market t is given by the multinomial logit expression:

$$s_{ijt} = \frac{e^{\delta_{jt}}}{1 + \sum_{k=1}^{J_t} e^{\delta_{kt}}} \tag{23}$$

where δ_{jt} is the mean utility common to all consumers and J_t remains the total number of products in the market at time t.

In the full random-coefficients model, we assume ε_{ijt} is i.i.d with a Type-I extreme-

value distribution but now allow heterogeneity in consumer preferences to enter through an additional term μ_{ijt}. This allows more general substitution patterns among products than is permitted under the restrictions of the multinomial logit model. The probability of individual i purchasing product j in market t must now be computed by simulation. This probability is given by computing the integral over the taste terms μ_{it} of the multinomial logit expression:

$$s_{jt} = \int_{\mu_{it}} \frac{e^{\delta_{jt}+\mu_{ijt}}}{1+\sum_k e^{\delta_{kt}+\mu_{ikt}}} f(\mu_{it})\, d\mu_{it} \tag{24}$$

The integral is approximated by the smooth simulator which, given a set of N draws from the density of consumer characteristics $P^*(d\zeta)$, can be written:

$$s_{jt} = \frac{1}{N}\sum_{i=1}^{N} \frac{e^{\delta_{jt}+\mu_{ijt}}}{1+\sum_k e^{\delta_{kt}+\mu_{ikt}}} \tag{25}$$

Given these predicted market shares, we search for demand parameters that implicitly minimize the distance between these predicted market shares and the observed market shares using a generalized method-of-moments (GMM) procedure, as we discuss in further detail in the estimation section.

5 The Market and the Data

In this section we describe the data and the market our data cover. The price data come from an industry data provider, *Edmunds.com*. The *Edmund*'s data include the following

variables on a monthly basis from 2002 to early 2005: Make, Model, Style Year, Base Manufacturer's Suggested Retail Price (MSRP) for both new and used models, Base Invoice (wholesale) Price for both new and used models, National Base Total Market Value (TMV) Price for both new and used models, Destination Charges, Gas Guzzler Tax, Luxury Tax, Dealer Holdback, Class, Where Built, Basic Warranty, EPA MPG Estimates, Fuel Tank Capacity, Horsepower, Length, Width, and Front Headroom. The Base TMV price is defined as the median retail sales price for each vehicle without adjusting for options, color, or region in which sold. The base invoice price less the dealer holdback (less any dealer incentives) makes up the observed wholesale price.

In this paper, we consider 19 models from the luxury segment of the market, as this enables us to estimate a very flexible demand system, a random-coefficients demand system, even with our limited observations. This segment has an unusually high share of foreign cars: It includes models made in Austria, Belgium, Canada, Germany, Japan, Sweden, the United Kingdom, and the United States. This allows us to highlight the role of strategic interactions between domestic and foreign manufacturers in the incomplete transmission.

These price data improve on previous studies in several ways, by enabling us to estimate marginal cost and pass-through coefficients at the make and model level, rather than at the market-segment level, as some previous studies do. Our price data are calculated from a sample of roughly 20 percent of all U.S. monthly auto sales. The TMV price is the median price paid for the base model. Finally, our study includes a wholesale price which allows us to decompose the role of local nontraded costs, and

to separate its role in the incomplete transmission from that of inefficiencies caused by firms' contractual form. We also observe transaction prices from the used-car market by make and model which we use as instruments for new car prices, as we discuss further in the estimation section. Finally, the monthly sales data come from *Ward's Automotive*.

Summary statistics for prices, characteristics, and market shares are provided in Table 1. We define a product as a base auto model. Quantity is the total number of each of the sample's models sold per month. We define the potential market as the total number of new models sold each month in the U.S.

6 Demand Estimation and Identification

This section describes the econometric procedures used to estimate the structural model's demand parameters. The results depend on consistent estimates of the model's demand parameters. Two issues arise in estimating a complete demand system in an oligopolistic market with differentiated products: the high dimensionality of elasticities to estimate and the potential endogeneity of price.[8] Following McFadden (1973), Berry, Levinsohn, and Pakes (1995), and Nevo (2001) we draw on the discrete-choice literature to address the first issue: we project the products onto a characteristics space with a much smaller dimension than the number of products. The second issue is that a product's price may be correlated with changes in its unobserved characteristics. We deal with this

[8] In an oligopolistic market with differentiated products, the number of parameters to be estimated is proportional to the square of the number of products, which creates a dimensionality problem given a large number of products.

second issue by instrumenting for the potential endogeneity of price. We use 2000 and 2001 model-year used-auto prices as instruments. Used auto prices should be correlated new car prices because they share some of the same features, but not with unobserved changes in consumer demand for new cars, perhaps stimulated by advertising campaigns (such as a taste for a more angled bumper), that affect both new prices and quantities demanded (see more on this below).

We estimate the demand parameters by following the algorithm proposed by Berry (1994). This algorithm uses a nonlinear generalized-method-of-moments (GMM) procedure. The main step in the estimation is to construct a moment condition that interacts instrumental variables and a structural error term to form a nonlinear GMM estimator. Let θ signify the demand-side parameters to be estimated with θ_1 denoting the model's linear parameters and θ_2 its non-linear parameters. We compute the structural error term as a function of the data and demand parameters by solving for the mean utility levels (across the individuals sampled) that solve the implicit system of equations:

$$s_t\left(x_t, p_t, \delta_t | \theta_2\right) = S_t \tag{26}$$

where S_t are the observed market shares and $s_t\left(x_t, p_t.\delta_t | \theta_2\right)$ is the market-share function defined in equation (*25*). For the logit model, this is given by the difference between the log of a product's observed market share and the log of the outside good's observed market share: $\delta_{jt} = \log(S_{jt}) - \log\left(S_{0t}\right)$. For the full random-coefficients model, it is

computed by simulation.[9]

Following this inversion, one relates the recovered mean utility from consuming product j in market t to its price, p_{jt}, its constant observed and unobserved product characteristics, d_j, and the error term $\Delta\xi_{jt}$ which now contains changes in unobserved product characteristics:

$$\Delta\xi_{jt} = \delta_t - \beta_j d_j - \alpha p_{jt} \tag{27}$$

We use brand fixed effects as product characteristics following Nevo (2001). The product fixed effects d_j proxy for the observed characteristics term x_j in equation (*18*) and mean unobserved characteristics. The mean utility term here denotes the part of the indirect utility expression in equation (*20*) that does not vary across consumers.

6.1 Instruments and Identification

The remainder of the paper relies heavily on having consistently estimated demand parameters or, alternatively, demand substitution patterns. The source of variation that identifies demand is the relative price variation over time. In this paper, the experiment asks consumers to choose between different products over time, where a product is perceived as a bundle of attributes (among which are prices). Since retail prices are not randomly assigned, we use used-car price level changes over time that are significant

[9] See Nevo (2000) for details. To ensure a global minimum, we start by using a gradient method (providing an analytical gradient) with different starting values of the non-linear parameters to find a minimum of the simulated GMM objective function. Then we use that minimum as a starting value for the Nelder-Mead (1965) simplex search method.

and exogenous to unobserved changes in new product characteristics to instrument for prices. These instruments separate variation in prices due to exogenous factors from endogenous variation in prices from unobserved product characteristics changes.

Instrumental variables in the estimation of demand are required because when retailers consider all product characteristics when setting retail prices, not only the ones that are observed. That is, retailers consider both observed characteristics, x_{jt}, and unobserved characteristics, ξ_{jt}. Retailers also account for any changes in their products' characteristics and valuations. A product fixed effect is included to capture observed and unobserved product characteristics/valuations that are constant over time. The econometric error that remains in ξ_{jt} will therefore only include the changes in unobserved product characteristics such as unobserved promotions and/or changes in unobserved consumer preferences. This implies that the prices in (*18*) are correlated with changes in unobserved product characteristics affecting demand. Hence, to obtain a precise estimate of the price coefficients, instruments are used, the z_{jt} that are orthogonal to the error term $\Delta\xi_{jt}$ of interest. The population moment condition requires that the variables z_{jt} be orthogonal to those unobserved changes in product characteristics stimulated by local advertising.

We use used-auto price data as instruments. Used prices should be correlated with new auto prices, which affect consumer demand, but are not themselves correlated with changes in unobserved characteristics that enter consumer demand. Used-auto prices are unlikely to have any relationship to the types of promotional activity that will stimulate perceived changes in the characteristics of the sample's products. The used-auto data

come from *Edmunds* as well, and are make, model, and model-year specific for used-auto sales for each month in the new-auto-price data. We use prices for 2000 and 2001 models.

One might expect used auto prices to be weakly correlated with new auto prices, thus generating a weak instrumental-variables problem.[10] The model's first-stage results, reported below, indicate that used auto prices appear to be valid instruments.

7 Empirical Results

We use the Logit model for demand as a basis for illustrating the need to instrument for prices when estimating demand. Understanding the drawback of having poor substitution patterns (see McFadden (1984) and Nevo (2000)), we then estimate a random-coefficients discrete-choice model of demand for differentiated products.

7.1 First-Stage and Logit Demand Results

The first-stage part of Table 3 reveals that the first-stage R-squared and F-statistic of the instrumental-variable specification are high and the F-test for zero coefficients associated with the used-car series as instruments is rejected at any significance level. This suggests that the instruments used are important in order to consistently estimate demand parameters. Considering the use of instruments for prices, the Hausman (1978) test for exogeneity suggests that there is a gain from using instrumental variables ver-

[10] Staiger and Stock (1997) examine the properties of the IV estimator in the presence of weak instruments.

sus ordinary least squares when estimating Logit demand. Table 3 presents the results from regressing the mean utility, which for the Logit case is given by $ln(s_{jt})$-$ln(s_{0t})$, on prices and product dummy variables in equation (*18*). The second column displays the estimate of ordinary least squares for the mean price coefficient alpha, and column three contains estimates of alpha for the instrumental variables (IV) specification. The consumer's sensitivity to price should increase after we instrument for unobserved changes in characteristics. That is, consumers should appear more sensitive to price once we instrument for the impact of unobserved (by the econometrician, not by firms or consumers) changes in product characteristics on their consumption choices. It is promising that the price coefficient falls from -1.30 in the OLS estimation to -4.35 in the IV estimation.

7.2 Random-Coefficients Demand Results

In Table 4 we report results from estimation of the demand equation (*27*). We allow consumers' unobservable characteristics to interact with their taste coefficients for price and foreign vehicles. As we estimate the demand equation using product fixed effects, we recover the consumer taste coefficients for constant (time invariant) product characteristics in a generalized-least-squares regression of the estimated product fixed effects on product characteristics. This GLS regression assumes changes in models' unobserved characteristics $\Delta\xi$ are independent of changes in models' observed characteristics x: $E(\Delta\xi|x) = 0$.

The coefficients on the characteristics appear reasonable. The mean preference in

the population is positive towards foreign models, more horsepower, and greater fuel efficiency. These characteristics have positive and mostly significant coefficients. The interaction of the foreign dummy variable with unobservables is high, at 3.98, and significant, indicating significant heterogeneity in the population with respect to this characteristic. The minimum-distance weighted R^2 is 0.48 indicating these characteristics explain the variation in the estimated product fixed effects fairly well. This estimated demand system produces a median own-price demand elasticity of -4.83 for the sample's models.

Table 5 reports the retail prices and the derived vertical price-cost markups (combined markups of all firms along the distribution chain) by market segment. Foreign brands' median retail price of $46,351 is about 25-percent higher than that of domestic models, at $36,805. The vertical markup is higher in the arm's-length model than in the vertically-integrated model, illustrating in part the double-marginalization externality associated with independent optimization by manufacturers and retailers along a distribution chain.

8 Results from Counterfactual Experiments

Using the full random-coefficients model and the derived marginal costs we conduct counterfactual experiments to analyze how firms and consumers react to foreign cost shocks. This section presents and discusses the results from these experiments.

8.1 Pass-Through Elasticities

The first counterfactual experiment considers the effect of a 10-percent dollar appreciation on foreign models' retail prices given each vertical supply model. Its results are reported in Table 6. The table's first column reports the median retail-traded pass-through elasticities for the arms-length model (AL). The second column reports the median retail-traded pass-through elasticities for the vertically-integrated multinational (MN) model. The median retail-traded pass-through elasticity is higher in the MN model than in the AL model. The median retail-traded pass-through elasticity is 44 percent for the AL model and 16 percent for the MN model, a 28 percentage-point difference. This leaves 56 percent of the original shock to be accounted for by the decomposition for the MN model and 84 percent for the AL model.

Pass-through elasticities vary for the arm's-length model from 4 percent for the *Jaguar X-Type* model to 32 percent for the *Lexus LX470*. The *Acura TL* has 20 percent of its content sourced from Canada. It is interesting that the pass-through elasticity on this model's imported content is roughly of the same magnitude as the pass-through elasticities for autos that are fully-assembled when they reach the U.S. border. Pass-through in the multinational model ranges from 36 percent for the *Mercedes-Benz C-Class* to 53 percent for the *Lexus LX470*. The difference in firms' pass-through across the two scenarios is smallest for the *Mercedes-Benz C-Class* and the *Lexus LX470*, at 21 percentage points, and highest for the *Jaguar X-Type* and the *BMW 5-Series*, at 35 percentage points. The difference is statistically significant for almost every model individually.

For all foreign models together, the median difference in pass-through across the two scenarios is 29 percentage points, which is statistically significant at the 5-percent level, as reported in Table 6.

Overall, Table 6 shows that the consumer is most insulated from exchange-rate changes when there are multiple optimizations along a distribution chain. The median retail-traded pass-through elasticity in the arms-length model is roughly one-third of its value in the multinational model.

8.2 Decomposition

Tables 7 and 8 decompose the sources of this incomplete transmission for the arm's-length and multinational models, respectively. The median results across all 26 models are illustrated in Figures 7 and 8. The first column of Table 7 reports the share of the incomplete transmission that can be attributed to a local-cost component in manufacturers' marginal costs. The second column reports the share that can be attributed to markup adjustment by manufacturers following the shock. The third column reports the share attributable to a local-cost component in retailers' marginal costs, and the fourth column the share attributable to the retailer's markup adjustment. Similarly, the first column of Table 8 reports the share of the incomplete transmission that can be attributed to a local-cost component in the multinational's marginal costs and the second column reports the share that can be attributed to markup adjustment by the multinational following the shock.

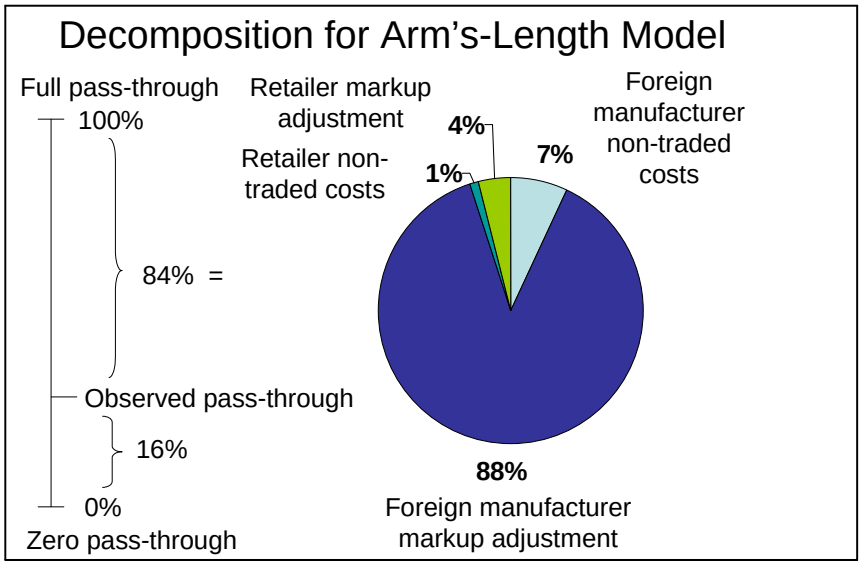


Figure 7: *Decomposition for the Arm's-Length Model.*

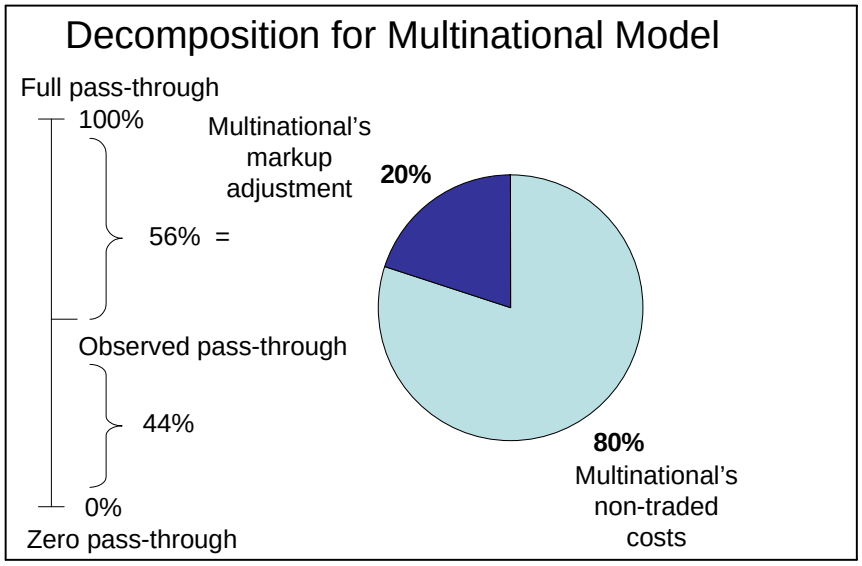


Figure 8: *Decomposition for the Multinational Model.*

In the AL model, manufacturers' markup adjustment plays the most significant role in the incomplete transmission of the original shock to retail prices. Following a 10-percent dollar appreciation, manufacturers' local-cost components account for 10 percent of the price adjustment, its markup adjustment for 80 percent, the retailer's local-cost component for 8 percent, and its markup adjustment for 2 percent. Overall, local-cost components account for 18 percent and firms' markup adjustments account for 82 percent of the incomplete transmission. These results are similar to recent work by Betts and Kehoe (2005) who show that fluctuations in nontraded-goods prices account for roughly 30 percent of the variation in real exchange rates, which implies that firms' markup adjustments on traded goods may account for the remaining 70 percent. In contrast, in the MN model, where one does not allow the downstream markup to vary with the shock, these shares are reversed, so non-traded costs account for the bulk of the incomplete transmission. Assuming downstream markups do not vary, as is the norm now in the macroeconomic literature on cross-border transmission (e.g. Burstein, Neves, and Rebelo (2003), Campa and Goldberg (2005), Corsetti and Dedola (2005)), may, thus, lead to seriously biased inferences as to the sources of incomplete transmission.

9 Conclusion

This paper shows that the organization of firms has a clear relationship to their transmission of shocks across borders. A significant portion of incomplete cross-border transmission may result from successive optimizations by firms along a distribution chain that

spans national borders.

Our work has several implications. First, an exchange-rate shock's overall effect on an economy will vary in its magnitude and its distribution across domestic firms, foreign firms, and consumers depending on the vertical contract that dominates the economy's import and export sectors. Second, treating downstream markups as a fixed wedge may obscure the fundamental causes of incomplete transmission. As many papers in the incomplete-transmission literature make this assumption, the estimates of the literature as a whole may overstate the importance of local nontraded costs relative to firms' markup adjustments.

Future research might explore the implications of these findings for exchange-rate pass-through patterns across countries with different industry mixes, and thus, dominant vertical contracts, in their import and export sectors. To give an example, most rich-rich country trade is multinational, while most rich-poor country trade is arm's-length. It is worth exploring how much of the stylized facts about how developed and developing economies respond differently to external shocks can be attributed to the dominant form of firm organization each type of trade's traded-goods sector and the resulting transmission of foreign shocks to the domestic economy.

References

[1] Anderson, James E. and Eric Van Wincoop. "Trade Costs," *Journal of Economic Literature*, *42*(3):691–751 (September 2004).

[2] Berry, Steven, James Levinsohn and Ariel Pakes. "Automobile Prices in Market Equilibrium," *Econometrica*, *63*(4):841–90 (July 1995).

[3] Berry, Steven. "Estimating Discrete-Choice Models of Product Differentiation," *RAND Journal of Economics*, *25*(2):242–62 (Summer 1994).

[4] Betts, Caroline and Michael Devereux. "Exchange Rate Dynamics in a Model of Pricing to Market," *Journal of International Economics*, *50*:215–44 (February 2000).

[5] Betts, Caroline and Timothy Kehoe. "U.S. Real Exchange-Rate Fluctuations and Relative Price Fluctuations," *The Journal of Monetary Economics* (2005).

[6] Brenkers, Randy and Frank Verboven. "Liberalizing a Distribution System: The European Car Market," *CEPR Discussion Paper*, (3622) (2002).

[7] Bresnahan, Timothy F. "Competition and Collusion in the American Automobile Industry: The 1955 Price War," *Journal of Industrial Economics*, *35*(4):457–82 (June 1987).

[8] Bresnahan, Timothy F. and Peter C. Reiss. "Dealer and Manufacturer Margins," *Rand Journal of Economics*, *16*(2):253–68 (Summer 1985).

[9] Burstein, Ariel, Joao Neves and Sergio Rebelo. "Distribution Costs and Real Exchange-Rate Dynamics," *Journal of Monetary Economics* (September 2003).

[10] Burstein, Ariel, Martin Eichenbaum and Sergio Rebelo. "Large Devaluations and the Real Exchange Rate," *Journal of Political Economy* (August 2005).

[11] Campa, Jose Manuel and Linda S. Goldberg. "Do Distribution Margins Solve the Exchange-Rate Disconnect Puzzle?," *FRBNY Mimeo* (2004).

[12] Campa, Jose Manuel and Linda S. Goldberg. "Exchange-Rate Pass-Through Into Import Prices: A Macro or Micro Phenemenon?," *Review of Economics and Statistics* (September 2005).

[13] Chevalier, Judith A., Anil K. Kashyap and Peter E. Rossi. "Why Don't Prices Rise during Periods of Peak Demand? Evidence from Scanner Data," *The American Economic Review*, *93*(1):15–37 (March 2003).

[14] Corsetti, Giancarlo and Luca Dedola. "Macroeconomics of International Price Discrimination," *Journal of International Economics* (2005).

[15] Devereux, Michael B., Charles Engel and Cedric Tille. "Exchange Rate Pass-Through and the Welfare Effects of the Euro," *International Economic Review*, *44*(1):223–42 (February 2003).

[16] Dixit, Avinash K. "Hysteresis, Import Penetration, and Exchange Rate Pass-Through," *Quarterly Journal of Economics*, *104*(2):205–28 (May 1989).

[17] Dornbusch, Rudiger. "Exchange Rates and Prices," *The American Economic Review*, *77*(1):93–106 (March 1987).

[18] Engel, Charles. "Accounting for US Real Exchange Rate Changes," *Journal of Political Economy*, *107*(3):507–38 (June 1999).

[19] Engel, Charles and John H. Rogers. "Deviations from Purchasing Power Parity: Causes and Welfare Costs," *Journal of International Economics*, *55*(1):29–57 (October 2001).

[20] Evans, Carolyn. "The Economic Significance of National Border Effects," *The American Economic Review*, *93*(4):1291–1312 (September 2003).

[21] Feenstra, Robert C., Joseph E. Gagnon and Michael M. Knetter. "Market Share and Exchange Rate Pass-Through in World Automobile Trade," *Journal of International Economics*, *40*(1-2):187–207 (February 1996).

[22] Feenstra, Robert C. "Symmetric Pass-Through of Tariffs and Exchange Rates Under Imperfect Competition: An Empirical Test," *Journal of International Economics*, *27*:25–45 (1989).

[23] Feenstra, Robert C. "Integration of Trade and Disintegration of Production in the Global Economy," *The Journal of Economic Perspectives*, *12*(4):31–50 (Autumn 1998).

[24] Froot, Kenneth A. and Paul D. Klemperer. "Exchange Rate Pass-Through When Market Share Matters," *The American Economic Review*, *79*(4):637–54 (September 1989).

[25] Goldberg, Pinelopi Koujianou. "Product Differentiation and Oligopoly in International Markets: The Case of the US Automobile Industry," *Econometrica*, *63*(4):891–951 (July 1995).

[26] Goldberg, Pinelopi Koujianou and Michael M. Knetter. "Goods Prices and Exchange Rates: What Have We Learned?," *Journal of Economic Literature*, *35*(3):1243–72 (September 1997).

[27] Goldberg, Pinelopi Koujianou and Frank Verboven. "The Evolution of Price Dispersion in the European Car Market," *Review of Economic Studies*, *68*:811–48 (2001).

[28] Hellerstein, Rebecca. "A Decomposition of the Sources of Incomplete Cross-Border Transmission," *FRBNY Staff Report*, (250) (April 2006).

[29] Hellerstein, Rebecca. "Vertical Contracts and Exchange Rates," *FRBNY Mimeo* (2006).

[30] Knetter, Michael M. "International Comparisons of Price-to-Market Behavior," *The American Economic Review*, *83*(3):473–86 (June 1993).

[31] Krugman, Paul R. "Pricing to Market When the Exchange Rate Changes." *Real-financial linkages among open economies* edited by Sven W. Arndt and J. David Richardson, 49–70, Cambridge, MA and London: MIT Press, 1987.

[32] McFadden, Daniel. "Conditional Logit Analysis of Qualitative Choice Behavior." *Frontiers of econometrics* edited by Paul Zarembka, 105–42, New York: Academic Press, 1973.

[33] McFadden, Daniel. "Econometric Models of Probabilistic Choice." *Structural analysis of discrete data* edited by Charles F. Manski and Daniel McFadden, 169–73, Cambridge: MIT Press, 1981.

[34] McFadden, Daniel and Kenneth Train. "Mixed MNL Models for Discrete Response," *Journal of Applied Econometrics*, *15*(5):447–70 (September-October 2000).

[35] Meese, Richard and Kenneth Rogoff. "Empirical Exchange Rate Models of the Seventies: Do They Fit Out of Sample," *Journal of International Economics*, *14*:3–24 (February 1983).

[36] Mortimer, Julie Holland. "Vertical Contracts in the Video Rental Industry," *Working Paper* (April 2004).

[37] Nevo, Aviv. "A Practitioner's Guide to Estimation of Random-Coefficients Logit Models of Demand," *Journal of Economics and Management Strategy*, *9*(4):513–48 (Winter 2000).

[38] Nevo, Aviv. "Measuring Market Power in the Ready-to-Eat Cereal Industry," *Econometrica*, *69*(2):307–42 (March 2001).

[39] Obstfeld, Maurice and Kenneth Rogoff. "The Six Major Puzzles in International Macroeconomics: Is There a Common Cause?." *NBER Macroeconomics Annual 2000* edited by Ben S. Bernanke and Kenneth Rogoff, 339–90, Cambridge: MIT Press, 2001.

[40] Rey, P. and T. Verge. "Resale Price Maintenance and Horizontal Cartel," *Mimeo CMPO Series No. 02/047 and Universit? des Sciences Sociales, Toulouse* (2004).

[41] Staiger, Douglas and James H. Stock. "Instrumental Variables Regression with Weak Instruments," *Econometrica*, *65*(3):557–86 (May 1997).

[42] Tille, Cedric. "The Role of Consumption Substitutability in the International Transmission of Monetary Shocks," *Journal of International Economics*, *53*(2):421–44 (April 2001).

[43] Villas-Boas, Sofia. "Vertical Contracts Between Manufacturers and Retailers: Inference with Limited Data," *CUDARE Working Paper*, (943) (2005).

[44] Villas-Boas, Sofia and Rebecca Hellerstein. "Identification of Supply Models of Retailer and Manufacturer Oligopoly Pricing," *Economics Letters*, *90*(1):132–40 (January 2006).

[45] Yi, Kei Mu. "Can Vertical Specialization Explain the Growth of World Trade?," *Journal of Political Economy*, *111*(1):52–102 (February 2003).

Description	Mean	Standard Deviation	Min	Max
Retail TMV price ($)	45,346	20,266	26,625	118,100
Retail Used TMV price, 2001 models ($)	31,052	13,279	15,444	79,736
Retail Used TMV price, 2000 models ($)	26,999	10,853	13,316	67,793
Market share of each product	.0048	.0035	.00065	.0186
Foreign (=1 if true)	.89	.31	0	1
Horsepower	249	54	190	445
Fuel efficiency	18	2	13	22

Table 1: *Summary statistics for prices and market shares for the 19 products in the sample.* The market share refers to the volume share of the product in the potential market which we define as all retail auto sales in the U.S. in that month. Source: *Edmund's: Ward's.*

Make and model	Where produced
Acura TL	United States
Acura MD	Japan
Audi A-4	Germany
BMW 3-Series	Germany
Lexus LX-470	Japan
Mercedes Benz SL-Class	Germany
Saab 9-3	Austria/Sweden
Volvo 70-Series	Belgium

Table 2: *A sample of foreign models and the production location of each.* Source: *Edmunds.*

Variable	OLS	IV	
Price	-1.3	-4.35	.
	(.27)	(.99)	
Adjusted R^2	.86		
Observations	494	494	
First-Stage Results			
F-Statistic		49.46	
Instruments		used prices	

Table 3: *Diagnostic results from the logit model of demand.* Dependent variable is $ln(S_{jt}) - ln(S_{ot})$. Both regressions include brand fixed effects. Based on 494 observations. Huber-White robust standard errors are reported in parentheses. Source: Authors' calculations.

Variable	Mean in Population	Interaction with Unobservables
Constant	-5.24*	
	(.91)	
Price	-24.44*	.67
	(5.83)	(3.00)
Horsepower	15.33*	
	(.91)	
Fuel Efficiency	9.31*	
	(4.58)	
Foreign	6.91	3.98*
	(4.67)	(1.00)
GMM Objective	0	
M-D Weighted R^2	.48	

Table 4: *Results from the random-coefficients model of demand.* Starred coefficients are significant at the 5-percent level. Source: Authors' calculations.

Product	Price	Vertical Markup		Percent of TMV Price	
	Retail	AL	MN	AL	MN
	($)	($)	($)	(%)	(%)
Model					
Domestic	$36,805	$9,045	$4,180	25	11
Foreign	$46,351	$13,808	$4,465	30	10
All	$46,346	$13,228	$4,375	29	9

Table 5: *Median retail prices and derived vertical price-cost markups by market segment.* Median across 26 markets. The markup is price less marginal cost with units in dollars per model. Source: Authors' calculations.

Model	AL	MN		AL	MN
EURO AREA			UK		
Audi A4	14	42	Jaguar S-Type	23	48
	(8.5)	(4.7)*		(7.6)*	(2.9)*
BMW 3-Series	10	40	Jaguar X-Type	4	39
	(6.6)	(4.8)*		(7.9)	(4.5)*
BMW 5-Series	13	48			
	(8.6)	(3.1)*			
Mercedes C-Class	15	36	JAPAN		
	(7.2)*	(6.1)*			
Mercedes E-Class	15	47	Lexus GS 300	12	43
	(9.2)	(3.9)*		(7.2)	(5.3)*
Volvo 60	16	41	Lexus LS 430	27	50
	(10.6)	(4.5)*		(7.6)*	(3.4)*
Volvo 70	15	42	Lexus LX 470	32	53
	(9.6)	(4.5)*		(7.1)*	(2.8)*
SWEDEN			CANADA		
Saab 3-September	11	44	Acura MDX	16	45
	(6.9)	(4.0)*		(9.4)	(3.6)*
Volvo 80	17	47			
	(9.3)	(3.2)*	Acura TL (20% foreign)	1	45
				(3.8)	(0.9)*
All Foreign	16	44	Difference NLMP-DM		29
	(9.8)	(6.1)*			(9.4)*

Table 6: *Counterfactual experiments: Retail traded pass-through of a 10% appreciation in the dollar for the two vertical-contractual scenarios.* Median pass-through over 26 markets. Retail traded pass-through is the retail price's percent change for a given percent foreign-cost shock. AL refers to the arm's-length scenario and MN to the multinational scenario. Standard errors are reported in parentheses; * significant at the 5% level. Source: Authors' calculations.

	Manufacturer		Retailer	
	Nontraded	Traded	Nontraded	Traded
Model				
Audi A4	7	87	1	5
BMW 3-Series	6	90	1	3
Lexus 470	7	86	2	5
Volvo 70 Series	7	83	2	8
All	7	88	1	4

Table 7: *Counterfactual experiments: Decomposition of the incomplete transmission of a 10-percent dollar appreciation in arms-length transactions.* Median over 26 markets. Manufacturer nontraded: the share of the incomplete transmission explained by the presence of a local component in manufacturer's marginal costs. Manufacturer traded: the share of the incomplete transmission explained by manufacturers' markup adjustment. Retail nontraded: the share of the incomplete transmission explained by the presence of a local component in the retailer's costs. Retail traded: the share of the incomplete transmission explained by the retailer's markup adjustment. Source: Authors' calculations.

	Nontraded Costs	Markup Adjustment
Model		
Audi A4	80	20
BMW 3-Series	76	24
Lexus 470	83	17
Volvo 70 Series	80	20
All	80	20

Table 8: *Counterfactual experiments: Decomposition of the incomplete transmission of a 10-percent dollar appreciation by multinationals.* Median over 26 markets. Nontraded: the share of the incomplete transmission explained by the presence of a local component in manufacturer's marginal costs. Traded: the share of the incomplete transmission explained by manufacturers' markup adjustment. Source: Authors' calculations.